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ABSTRACT

This book approaches the subject of leadership among science and mathematics teachers during times of educational reform from the perspective of local decision making, personal action, and respect of peers. The view of leadership presented in this book elevates the profession rather than the status of individuals, and the view is supported by positive outcomes in the everyday communities of schools. During the years of ongoing reform, education has focused on goals, standards, teacher preparation, materials, and curriculum frameworks. Ultimate success in reforming practice, however, will come when some key people at the local level lead the way in making decisions, taking action, and maintaining a resolve to improve practices grounded in tradition. This book consists of 15 chapters which highlight teacher leadership, professional development, teacher enhancement programs, and teachers' perspectives on science and mathematics education. (SAH)

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Developing Teacher Leaders

Professional Development in Science and Mathematics

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This book is dedicated to the memory of Susan Loucks-Horsley who contributed so much to children and teachers through her work in science and mathematics education.

Contents

Chapter Page

1. Teacher Leadership: A Promising Paradigm for Improving Instruction in Science and Mathematics 1
Leonard O. Pellicer & Lorin W. Anderson

2. What Evaluation Tells Us about Professional Development Programs in Mathematics and Science 17
Joy Frechtling

3. Findings from the Multi-Agency Study of Teacher Enhancement Programs 43
Joy Frechtling & Conrad Katzenmeyer

4. Effective Professional Development for Teacher Leaders: Lessons Learned from K-6 Mathematics Teacher Enhancement Programs 71
Susan N. Friel & George W. Bright

5. Designing Programs for Teachers Leaders: The Case of the California Science Implementation Network 89
Kathy DiRanna & Susan Loucks-Horsley

6. Building a Community for Science 113
Emma L. Walton

7. Developing and Maintaining Implementation of a Teaching-for-Thinking Program 127
Philip Adey & Alan Edmiston

8. Teacher Leadership Development as a Critical Component of Systemic Reform: The San Joaquin Valley Mathematics Project 147
Carol Fry Bohlin

9. The Emergence of Teacher Leaders Through Professional Development 175
Carol A. Thornton, Cynthia W. Longrall, Graham A. Jones, & Jane O. Swafford

10. Developing Chemistry and Mathematics Teacher Leaders in Israel 189
Avi Hofstein & Ruhama Even

11. Teachers' Perspectives: Developing Instructional Leadership Through Classroom Inquiry 209
Laura N. Rogers & Patricia D. Tyndall

12. In their Own Words: What Science and Mathematics Teacher Leaders Say are Important Aspects of Professional Development 227
Catherine R. Nesbit, Warren J. DiBiase, Anne-Courtney S. Miller, & Josephine D. Wallace

13. The Professional Development of Effective Teacher Leaders 245
Carol Langbort

14. Evaluation of Teacher Leader Professional Development Programs 267
Frances Lawrenz

15. Diversity, Technology, and Policy: Key Considerations in the Development of Teacher Leadership 289
David K. Pugalee, Jeffrey Frykholm, & Farella Shaka

Foreword

Each day that I drive to my office I pass by a flock of birds that live along a particular section of powerlines stretching parallel to the road. For years I have been trying to figure out why the birds crowd together in precisely the same area every day, year after year, despite what seem to be miles of perfectly fine, unpopulated powerlines. Whenever I pass this community of birds, they are either all flying as a flock, or all perched on the lines, with most of them facing the same direction. Seldom do I see individual birds off on their own, though some occasionally do take wing on their own. When they are all flying, it is almost as if they constitute one entity, all turning at the same instant, all ascending or descending at the same rate, or all swooping toward their homes on the powerlines together. My only explanation for the precision maneuvers and positioning is that there are both some leaders within that flock and a lot of followers who pay very close attention to the leaders. What is fascinating is that the leaders look just like the followers and fly among them; they do not have any special adornments that are obvious to me, and I can never pick out "who turned first." Some birds in that flock make decisions "on the fly" (forgive me) and those decisions affect the whole group. Apparently the decisions are good ones, because the flock continues to survive and prosper within its section on the powerlines.

Throughout our history and across cultures there have been many different modes of leadership cultivated and expressed through collective action. Some leaders stand out front and take charge, while others work from within through collaboration, mutual respect, and teamwork. Some leaders have been anointed by authorities for their distinctive roles, with special titles and privileges, while others emerge from within the ranks and avoid directing any attention to themselves. With such diversity in leadership styles, it seems difficult at first glance to discern the effective pathways to leadership. Whether thinking of human armies or flocks of birds, however, effective leadership involves making decisions, taking action, and influencing the behavior of others, the potential followers. Leadership does not seem to require a special heritage or rare human qualities, but it does require experiential knowledge, resolve, and the respect, whether forced or freely given, of those who choose to follow.

This timely book approaches the subject of leadership among science and mathematics teachers during times of educational reform from the perspective of local decision making, personal action, and respect of peers. The view of leadership presented in this book elevates the profession rather than the status of individuals, and the view is supported by positive outcomes in the everyday communities of schools. During the years of ongoing reform in education, we have focused on goals, standards, teacher preparation, materials, and curriculum frameworks. Ultimate success in reforming practice, however, will come when some key people at the local level lead the way in making decisions, taking action, and maintaining resolve to improve practices grounded in tradition. In the end, we may choose to remain in our small area along the powerlines, but we can continually improve the quality of our teaching and learning there by cultivating communities of leaders and followers who share visions of a shared future. I highly commend this book to anyone hoping to nurture the professional development of successful flocks. This book provides us with some valuable insights about promoting leadership among science and mathematics teachers, and that is where we must now turn the focus of reform efforts.

David L. Haury

Preface

Why should you read this book? Like most edited books, this one offers a variety of perspectives; authors write from within the context of their own experiences, and the chapters weave together a rich blend of theory and practice. But the main reason you should read this book is because it presents a viable way to bring science and mathematics reform initiatives to life in classrooms and schools. Teacher leaders are the critical key. When they are well prepared, empowered, and enthused, they can catalyze and sustain the spread of innovations among their colleagues in schools. Teacher leaders do this in a variety of ways. They present workshops, organize resources, observe other teachers and provide feedback, demonstrate new teaching methods, facilitate discussions, and involve other teachers in making decisions about mathematics and science teaching.

What makes teacher leaders effective in activating school reform? Because they are the right people in the right place at the right time.

- Teacher leaders have the trust of their faculty colleagues, an integral ingredient for introducing change in schools. They are first of all practitioners, familiar with the art and science of teaching. As practicing teachers, they lead from a position of direct experience as they try innovations with their own students first, model them for other teachers, and share outcomes with their colleagues. This dynamic interaction among peers opens doors to discussion, self-reflection and ultimately change in teaching practices.
- Working within the school context, teacher leaders are able to align innovations with school and district goals. As a result, others do not view the innovations as a "passing fancy" and more freely "buy into" implementing them.
- Having experiential knowledge of local school systems as well as a conceptual understanding of the innovations associated with reform, teacher leaders are in a position to gain the support of the whole educational community. They are in a

position to solicit support from key personnel within schools, and when teachers, department chairs, administrators, central office staff, and members of the community support innovations, they have a better chance of being implemented and sustained over time.

- Working through teacher leaders is an efficient and economical way to transform teaching at the school level. Because there are so many teachers and limited funding for professional development, it is generally not possible for all the teachers of a school to attend a professional development program. A viable alternative, then, is to have teacher leaders attend, and then share newly acquired knowledge and skills with school colleagues. When this occurs, all the teachers within a school have the opportunity to collaborate in a focused and supportive environment. This facilitates the change process.

To function effectively in the leadership role described above, teacher leaders must gain knowledge of mathematics and science content and pedagogy as well as leadership skills for working with adults. Teachers generally have neither the background nor the experiences to adequately prepare them for the new responsibilities. Consequently, effective professional development programs for preparing teacher leaders are needed.

The goal of professional development in leadership is to prepare teacher leaders to be successful change agents who can build collaboration and ownership among teachers in implementing school reform. This goal presents new challenges to those who design professional development programs, and the new challenges require programs that are more complex and multidimenstional than the traditional "train the trainer" model. This book describes well-designed professional development programs that include innovative characteristics for preparing teacher leaders.

How is the book organized? The book includes fifteen chapters that form three clusters. The first four chapters set the context for the rest of the book. Topics covered include: definitions of teacher leaders and their roles in schools, goals of professional development programs and how to measure their impact, and the need to validate the effectiveness of teacher leaders in initiating and maintaining change at their schools.

The next nine chapters form the main body of the book and describe specific professional development programs for teacher leaders. The programs vary, with some focusing on mathematics, some on science, and others on both subject areas. The programs also vary in the targeted grade levels: elementary, middle grades, secondary, and some K-12. Programs representative of different regions in the United States are presented. In addition, two international programs are described. Finally, some chapters present research findings while other chapters are more descriptive in nature.

The final two chapters bring closure to the book by summarizing principles of effective professional development for teacher leaders and practical advice on evaluating professional development programs. The book concludes with a chapter that offers recommendations for the future. Following are brief descriptions of each chapter:

- Chapter One, *Teacher Leadership: A Promising Paradigm for Improving Instruction in Science and Mathematics,* builds a case for the importance of developing teacher leadership to facilitate successful school change. In addition, the chapter describes challenges facing schools as they implement teacher leadership practices.
- Chapter Two, *What Evaluation Tells Us about Professional Development Programs in Mathematics and Science,* begins with the educational priorities of the 20Th century and the resulting professional development programs. This provides a historical setting for considering the goals of present-day professional development and the accompanying criteria used for assessing attainment of these goals.
- Chapter Three, *Findings from the Multi-Agency Study of Teacher Enhancement Programs*, presents the best practices of professional development programs that have impacted teachers. The chapter also illustrates the need for evaluating the impact of teacher leaders on school dissemination.

- Chapter Four, *Effective Professional Development for Teacher Leaders: Lessons Learned from K-6 Mathematics Teacher Enhancement Programs*, summarizes principles useful for designing effective professional development programs. These principles are drawn from successful teacher enhancement programs supported by the National Science Foundation.
- Chapter Five, *Designing Programs for Teachers Leaders: The Case of the California Science Implementation Network*, presents an elementary science program that evolved into a K-12 network composed of several program partnerships. The program's successes and failures are analyzed using a professional development design framework developed by the National Institute for Science Education.
- Chapter Six, *Building a Community for Science*, explores how a professional development program for elementary teachers matured over 25 years using a systemic approach involving teachers, principals, other administrators and community members.
- Chapter Seven, *Developing and Maintaining Implementation of a Teaching-for-Thinking Program*, describes a professional development program for middle school teachers that has resulted in long term achievement for students in England. The chapter presents examples of how teacher leaders have molded the program to fit the needs of individual schools and school systems. The second author of this chapter is a teacher leader.
- Chapter Eight, *Teacher Leadership Development as a Critical Component of Systemic Reform: The San Joaquin Valley Mathematics Project*, examines a professional development program which is part of a large scale, long term, statewide project for K-12 mathematics teachers.
- Chapter Nine, *The Emergence of Teacher Leaders Through Professional Development*, describes an algebra project designed for middle and secondary school teachers. This program is unique in that it did not attempt to identify teacher leaders but allowed them to evolve as they progressed through the program.

- Chapter Ten, *Developing Chemistry and Mathematics Teacher Leaders in Israel*, presents two professional development programs for preparing secondary teacher leaders, one in chemistry and one in mathematics. These programs are representative of professional development programs offered at National Centers established throughout Israel to bring about educational reform.
- Chapter Eleven, *Teachers' Perspectives: Developing Instructional Leadership through Classroom Inquiry*, describes projects in a Professional Development System, a university-public school partnership. The chapter illustrates the teachers' passage through stages of leadership and inquiry teaching. This chapter is co-authored with a teacher leader.
- Chapter Twelve, *In Their Own Words: What Science and Mathematics Teacher Leaders Say are Important Aspects of Professional Development*, describes the components of professional development that elementary teacher leaders report as being helpful in implementing their leadership responsibilities.
- Chapter Thirteen, *The Professional Development of Effective Teacher Leaders*, describes a fifteen-year-old mathematics program for elementary and middle schoolteachers. It reports positive results showing the impact of the program on the knowledge and the role of teacher leaders.
- Chapter Fourteen, *Evaluation of Teacher Leader Professional Development Programs*, focuses on how to evaluate different effects of professional development programs for teacher leaders.
- Chapter Fifteen, *Diversity, Technology, and Policy: Key Considerations in the Development of Teacher Leadership*, presents three areas recommended for future consideration. The authors describe practical ways teacher leaders can influence change in these areas.

1

Teacher Leadership: A Promising Paradigm For Improving Instruction In Science And Mathematics

Leonard O. Pellicer &
Lorin W. Anderson
University of South Carolina

Without question teacher leadership is more important today to the success of America's schools than it has ever been before. As schools and the populations they serve have grown in size and complexity, principals can no longer be expected to be the sole, or even the primary source, of instructional leadership. This realization has come about as a result of the series of reform waves that swept across the American educational landscape during the past two decades. Although teachers traditionally have had limited authority to exercise control over conditions that affect students in their classrooms, school boards and school administrators traditionally have exercised almost total control over conditions that have shaped the working lives of teachers. The results of systematically excluding teachers from meaningful participation in decision making over the years should have been all too predictable--stagnation of the teaching profession and the failure of American schools. Nowhere is teacher leadership more needed than in the highly technical and critical content areas of science and mathematics. In addition to a discussion of the conditions that have led to the realization that teacher leadership is no longer a luxury but a necessity if schools are to succeed, this chapter gives attention to the need to professionalize teaching by promoting teacher leadership. The qualities and characteristics of teacher leaders as reported in the literature are summarized and the chapter concludes with a description of the challenges that confront educators in their attempts to embrace teacher leadership.

Without question, teacher leadership is more important today to the success of America's schools that it has ever been before. Schools have grown substantially larger and academic programs have become increasingly complex. A greater number of young Americans, from

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Note.This chapter is an update of a more extensive publication on teacher leadership: Pellicer, L., & Anderson, L. (1995). *A Handbook for Teacher Leaders*. Corwin Press, Inc., Thousand Oaks, CA far more diverse backgrounds, come to school at increasingly earlier stages in their lives and remain in school longer than they ever have. In addition, more of today's students bring with them to school an increasingly complex array of educational, social, physical, and psychological problems that stubbornly defy even the most creative solutions.

At the same time that schools and the populations they serve have grown in size and complexity, the American system of schooling has become a particularly attractive target for political leaders who have given voice to the demands of the citizenry that schools do more of what they are supposed to be doing better than they have ever done it before. Since there still remains a rather substantial difference of opinion in this country in regard to exactly what schools should be doing, this has confounded educators who are struggling to meet the standards placed squarely on their shoulders by accountability systems that currently are inadequate to measure meaningful results.

So what does teacher leadership have to do with all this? Quite simply, if schools are to successfully meet the challenges of the times, then teachers have to play a greater role in providing key leadership at all levels. Teachers must be treated as equal partners in decision making because they bring a wealth of experience and information to the table that can be used to significantly improve teaching and learning in America's schools. The National Teacher Forum (April, 1998) has identified several ways in which teachers can lead: participating in professional organizations, being involved in school decisions, defining what students need to know and be able to do, sharing ideas with colleagues and mentoring new teachers, helping with personnel decisions, becoming leaders in the community, leading efforts to make the work of teachers more visible while still communicating positive messages about schools and teaching, and creating partnership with the community, businesses and organizations, and colleges and universities. These are all critical leadership roles that teachers must increasingly assume.

Nowhere is teacher leadership more needed than in the highly technical and critical content areas of science and mathematics. In the remainder of this chapter, we discuss the conditions that have led to the realization that teacher leadership is no longer a luxury, but a necessity if schools are to succeed. We also give some attention to the need to professionalize teaching while promoting teacher leadership and explain why principals cannot do the job alone. The qualities and characteristics of teacher leaders are summarized, and the chapter concludes by describing the challenges that confront us in our attempts to embrace teacher leadership.

Why Teacher Leaders?

For much of the past 15 years educators have been overwhelmed by an avalanche of reports from a wide assortment of blue ribbon commissions, committees, and task forces all declaring that American education is broken and suggesting ways to fix it. *A Nation at Risk* (1983) was the first report of this time period to gain public attention on a grand scale. *A Nation at Risk,* in concert with a flood of similar reform reports issued in its aftermath, spawned an unprecedented flood of public outrage in protest of what was perceived as the complete and total failure of the American system of public schooling. It is important to note that this is not the first time that American education has come under attack (see, for example, Alkin, 1942, and Silberman, 1970). Critiques and responses of education in this country seem to be as American as apple pie. During the intervening years since this great flood of reform reports, state legislatures have struggled mightily to pass massive school reform programs to address the perceived ills of America's schools.

The first major wave of school improvement efforts followed closely on the heels of *A Nation at Risk* (1983) and crested in a mountain of state mandates and regulations designed to reform almost every aspect of American public schooling including, but not limited to, attendance requirements and academic standards for students, professional licensure requirements and performance standards for teachers, and student contact hours, curricula, and accountability measures for schools.

Unfortunately, these massive efforts to reform American education met with disappointing results. Despite all the time, energy, and fiscal resources invested, the expected results were never achieved. However, these efforts did produce more and longer school days, tighter attendance requirements, more tests for students with higher standards for success, and more stringent requirements to enter into and remain in the teaching profession. But when this first major reform wave receded from the American educational landscape, what remained for the most part, was a great deal more work, stress, and frustration for teachers, staff, and administrators, with only very modest gains for students.

The false assumption that drove the first big reform wave of the 1980s was that the chief problem with American education could be found in watered-down curricula, low academic standards for students, and lax accountability measures for teachers, administrators, and schools. That assumption was essentially flawed, but served to teach educators and politicians a valuable lesson. Simply doing more of the same thing, even if we did it a little better, would not produce the results we were hoping to achieve.

The late 1980s witnessed the birth of a second major wave of school reform aimed at restructuring public schools. The intent behind restructuring schools was to do the business of education in a different way by redesigning roles and relationships to get the job done more effectively and efficiently. In the words of Ann Lieberman of Teachers College, the call for restructuring schools, "raises issues of fundamental change in the way teachers are prepared, inducted into teaching, and involved in leadership and decision making at the school level" (1988, p. 4). As such, restructuring represents an important evolution in our thinking about education because the underlying assumption behind restructuring is that the chief problems with American public school education resides in the structure of schools and in the roles teachers and principals play in those schools, not in the curriculum, academic standards, or accountability measures that happen to be in place. This is an important insight for a number of reasons.

For more than 100 years, American schools have operated on a 19th century industrial model that casts principals in the role of management and teachers in the role of labor. Perhaps more than anything else, this outmoded model has contributed to fractured school communities where there are few shared values and no clear consensus on the most appropriate educational outcomes for students or the best means to achieve those outcomes. Consequently, few school communities have a consensual, shared vision of what they should or can be. This lack of a shared vision has limited the effectiveness of schools and created adversarial relationships where teachers and principals are pulling in opposite directions more intent on maintaining a balance of power than in achieving a common dream.

There can be little doubt in anyone's mind that schools need a transformation in terms of how they have been organized and how the people in them have worked together to meet the needs of students. The old assumption that the *principal must be the instructional leader* of a school is no longer relevant. In fact, the rigid, bureaucratic, organizational structure encouraged by this kind of thinking has been largely responsible, during the last century, for preventing teachers from exercising the kind of leadership that could bring about the long-awaited rebirth of schooling in America.

Although teachers traditionally have had limited authority to exercise control over conditions that affect students in their classrooms, school boards and school administrators traditionally have exercised almost total control over conditions that have affected the working lives of teachers. The results should have been all too predictable—stagnation of the teaching profession and the failure of American schools.

Many of us now believe that effective instructional leadership requires a partnership between teachers and principals. It's no longer enough for a principal to have a vision for what a school can be. If we have learned anything during the past 15 years, it's that teachers and principals must share a vision of what a school can be. In order for schools to excel, teachers, as well as principals, must take responsibility for providing the leadership that is required to create this common vision. In the words of Peter Senge (1990):

> *A shared vision is not an idea. It is not even an important idea such as freedom. It is, rather, a force in people's hearts, a force of impressive power. It may be inspired by an idea, but once it goes further—if it is compelling enough to acquire the support of more than one person—then it is no longer an abstraction. It is palpable. People begin to see it as if it exists. Few, if any forces in human affairs are as powerful as shared vision. (p.206)*

In answer to the question, "Why teacher leaders?" the answer is really quite simple. Principals cannot do the job alone--they never could do it and they never will be able to do it! As Senge has noted, without the support of more than one person, a vision is just an abstraction. It takes principals and teachers working together to transform this abstraction into meaningful reality. Without question, teachers have important leadership roles to play in their schools.

The Need to Professionalize Teaching

We have mentioned the factory model of schooling and the impact it has had on "de-professionalizing" teaching. Teaching can never be regarded as a true profession as long as people cling to the notion that principals are the managers of the school enterprise and teachers are the workers. This view presents an insurmountable obstacle to tapping the vast leadership resources available in the teaching force and cripples any attempts to truly restructure schools.

In a restructured school, the principal's most important task is to organize and cultivate the talents of all of the players in the school, thus providing a dynamic new kind of leadership. In a restructured school, teachers' roles must be expanded; they must make decisions that affect not only the students in their classrooms, but also other teachers and even the entire school community.

The reaction to this new role for teachers has been mixed. Although some teachers have willingly embraced it, others have been more hesitant. Even some of those who have embraced new roles for teachers have serious questions about how their new roles and responsibilities should be defined. Many lack confidence in their ability to perform some of the new tasks expected of them. Although many teachers have consistently demonstrated their ability to lead, some have not had an ample opportunity to develop and practice leadership skills. Some prospective teacher leaders fear the chasm the new roles might place between them and their colleagues; others are called on to assume responsibility but are unsure of the authority they have been given or whether they even want that authority. In many settings, teacher leadership roles are still ambiguous, and many teachers are frightened by that ambiguity.

If teachers are to get past these concerns and function as true professionals, principals must change the way they function as leaders. Although schools have developed new mission statements and implemented strategic planning and site-based management in recent years, most are not set up to accept teachers in leadership roles and "often discourage teachers from taking on additional responsibilities" (Creighton, 1997, p. 1). Principals must make it a priority to secure, maintain, and provide an adequate array of resources and support services that will enable teachers to perform the work for which they have been certified and employed. An important part of that work should focus on teachers providing instructional leadership for their colleagues.

If the education community truly desires to professionalize teaching, then it must alter its conception of teachers and teaching. In this regard, some of the fundamental practices and policies that presently encourage the rationalization or routinization of teaching must be changed. School leaders must dispense with ineffective evaluation systems that fail to recognize the complexity of teaching, spurn peer review, and cause principals to act as supervisors. They must halt competition for teacher loyalty and eliminate teacher isolation by bringing professional educators together to engage in meaningful dialogue. They must regard the work of teaching as mission-bound, rather than as time-bound.

Most important, however, school districts must shift a major portion of the responsibility for instructional leadership from principals to teachers. Such a shift enables principals to do better what they do (be administrators), while at the same time permits teachers to do better what they do best (make and act on decisions in the best interest of their students). Lieberman, Saxl, and Miles (1988) cut to the heart of the matter:

> *It is paradoxical that, although teachers spend most of their time facilitating for student learning, they themselves have few people facilitating for them and understanding their needs to be recognized, encouraged, helped, supported, and engaged in professional learning. Perhaps this is what we mean by "professionalizing" teaching and "restructuring the work environment" of teachers. (p. 152)*

As Little (1988) noted, even the most conservative workplace reform proposals require teachers to "act differently toward their work and one another..." and "to take the *lead* [italics added] in advancing the understanding and practice of teaching" (p. 82).

Principals Can't Do It Alone

About a decade ago, we were part of a national research team that conducted an in-depth study of instructional leadership in American high schools (Pellicer, Anderson, Keefe, Kelley, & McCleary, 1990). Initially, our expectations were that, in accordance with the general thinking and attitudes reflected in the profession at that time, principals would assume primary responsibility for instructional leadership and be recognized by teachers as *the instructional leaders* in their schools. But that turned out not to be the case. We discovered convincing evidence that instructional leadership, at least in the most effective schools we studied, was a shared responsibility. In no instance did we find that the principal was the sole source of instructional leadership in an effective school, and only in isolated instances could the principal be characterized as a primary source. Surprisingly, most of these high school teachers told us that they "never sought the advice of the principal on instructional matters" and that discussions of instructional improvements tended to be "department centered," rather than "school centered." More often than not, department chairpersons were identified as the major source of instructional leadership in the secondary schools we studied.

This should not have been a surprising finding given the breadth and complexity of modern high school curricula. Principals simply do not have the knowledge and skills required to provide the primary leadership for so many diverse and divergent fields of knowledge. One of the authors of this chapter, Leonard, is a former high school principal. His teaching expertise was in the area of English where he was certified as a secondary language arts teacher. The other author, Lorin, was a secondary mathematics teacher. It would be patently ridiculous for anyone to assume that if Leonard happened to be the principal of the school where Lorin was teaching mathematics, that Leonard could provide substantive instructional leadership in Lorin's area of expertise. But this is exactly the kind of thinking that has led many of us to assume that the principal can and should be *the* instructional leader of a school.

The best that principals can hope to do in working with teachers to provide instructional leadership across a broad range of academic fields is to make a rough judgment as to how well teachers practice a generally accepted set of generic instruction skills (e.g. organizing classrooms, managing classrooms, planning instruction, delivering instruction, and assessing and evaluating students). At best, this might allow a principal to make a general estimate as to whether a teacher is competent or incompetent in terms of the application of that generally accepted set of teaching competencies--no more, no less. This estimate must necessarily be rough, because without in-depth content knowledge and, increasingly important, pedagogical content knowledge (Shulman, 1987), an observer of a teaching performance has no way of knowing if the teacher has chosen the *proper* learning objectives for a *particular* lesson, *matched* those objectives with the *most suitable* teaching techniques to communicate the selected content to the students, *employed* the selected teaching techniques *appropriately*, and, finally, *used* the *proper* formative and summative evaluative techniques to measure how well students have achieved the learning objectives. This is pretty complex material when put into the proper context. In order for a principal to really judge the effectiveness of a teacher in a given subject field, the principal would have to be at least the content knowledge and pedagogical content knowledge equal of the teacher in the subject field that was being taught. It is an extremely rare set of circumstances that would permit this situation to occur. For highly technical and complex fields such as mathematics and science, the principal will rarely be the content equal of the teacher since relatively few principals have mathematics or science teaching backgrounds. Even for those few principals who do, their content knowledge and pedagogical knowledge can quickly become obsolete because they do not have adequate time to maintain their academic edge with the pressing demands of their administrative responsibilities. The only reasonable conclusion that can result from the foregoing discussion is that principals simply can not be *the instructional leaders* for schools no matter how much they should be or want to be.

What Is Instructional Leadership?

So exactly what is instructional leadership? What is it that principals were not doing and that teachers were doing in the schools we studied? These are difficult questions to answer, even for those who are actively engaged in the instructional leadership process. More than 50 years of combined experience and research have led us to define *instructional leadership* as initiating, implementing and sustaining planned change in a school's instructional program, which is supported by the various constituencies in the school, and that results in substantial and sustained improvement in student learning.

The exercise of instructional leadership calls for providing vision and direction, resources, and support for teachers and students. As we wrote a few years ago, "Instructional leadership begins with an attitude, an expressed commitment to student growth and productivity, from which emanates values, behaviors, and functions deliberately designed to foster, facilitate, and support student satisfaction and achievement" (Pellicer et al., 1990, p. 31).

We believe that the act of instructional leadership must be the responsibility of teachers if schools are to improve and if teaching is to achieve professional status. This assertion raises one final question: What do we know about teacher leaders that can provide us with a basis for improving teacher leadership in the areas of science and mathematics?

Teachers Who Lead

In addition to the obvious leadership behaviors that teachers display on a daily basis in their classrooms, teachers have for more than a century assumed formal leadership roles in their schools. Department chairpersons, team leaders, lead teachers, grade-level chairs, curriculum teachers, consultants, master teachers, and mentors are just a few of the important formal leadership roles fulfilled by teachers over the years. Hatfield, Blackman, Claypool, and Master (1987) estimated that from 10% to 20% of the teaching staff are engaged in leadership roles designated by more than 50 titles. In these formal roles, as well as in a variety of less formal roles such as members or chairpersons of formal and informal study groups and committees, teachers have served as planners, initiators, developers, facilitators, promoters, ombudspersons, problem solvers, nurturers, values clarifiers, and catalysts for individual and school-wide change and improvement. Without question, teachers have always been leaders, regardless or whether or not their leadership has been fully acknowledged.

We believe that titles are relatively unimportant. Whether a teacher leader is called a lead teacher, department chairperson, grade chairperson, curriculum coordinating teacher, master teacher, or whatever is less important than the functions he or she performs and the ability of that leader to establish and maintain acceptance and credibility with those he or she leads. Leadership involves change, and change requires the ability to take others where they would not normally go. Wasley (1991) defined teacher leadership as "the ability . . . to engage colleagues in experimentation and then examination of more powerful instructional practices in the service of more engaged student learning" (p.170). We like this definition; it is focused on children and instruction and denotes change in a positive direction.

To function as leaders, teachers who lead engage in a wide variety of behaviors. They assume responsibility for the continued development of their professional colleagues. They mentor those new to the profession by serving as role models. They provide leadership in content areas by producing instructional materials and creating positive work environments under trying circumstances. And for the most part, teacher leaders engage in these leadership activities while continuing to teach their own classes of students (Lieberman, 1988; Wasley, 1991).

Lieberman et al. (1988) added to and expanded on this list of teacher leadership roles and responsibilities. In a multiyear study of 17 teachers in a variety of teacher leadership roles, Lieberman and her colleagues found that successful teacher leaders employed a set of skill clusters that allowed them to (a) build trust and rapport, (b) examine issues within an organizational context, (c) build skill and confidence in others, (d) use resources wisely and efficiently, (e) deal with the change process, and (f) engage in collaborative work with teaching colleagues. From the results of their study, they concluded that "finding ways to create structures for teachers to work together, to focus on the problems of their school, to enhance their repertoires of teaching strategies--all are part of the work of teachers who work with other teachers" (p. 6).

O'Connor and Boles (1992) reported the results of a survey of Massachusetts teacher leaders on the nature of their roles and the support they needed to be successful in those roles. These researchers found that a significant majority of their sample of teacher leaders was involved in curriculum leadership, grade-level or departmental decision making, and staff development. The vast majority had conducted workshops and seminars for other teachers; most had served as mentors for other teachers. The major roadblocks to effectiveness in their leadership roles were a lack of time, unsatisfactory relationships with other teachers and administrators, and a lack of fiscal resources to get the job done. In terms of the additional skills and knowledge they needed in order to be more effective, teacher leaders in Massachusetts cited the need for a more complete understanding of the politics of schools, increased power and authority, better interpersonal relationships, and better communications skills in group dynamics, presentation skills, and organizational skills.

Wasley (1991), in her revealing in-depth case study of three teacher leaders, was struck "by how enormously complex teacher leadership roles are as they play out in practice" (p. 154). She noted that the roles involved power, authority, decision making, and different kinds of collaboration. Wasley's work strongly reinforces the notion that both teaching and leading are exhausting, even more so when they are done simultaneously. Furthermore, in most cases, there are no real incentives for teachers to lead; apparently they lead because they believe in what they are trying to accomplish. In other words, they are motivated by internal forces, rather than external factors.

Established teacher leadership roles, such as department chairpersons and team leaders, when contrasted with emerging teacher leadership roles, such as those highlighted in Wasley's study of teacher leaders, can lead to significant role confusion. Teacher leaders are teachers first, but they also are rare individuals who differ in significant ways from many of their colleagues. It is not surprising that all of these circumstances together can mean that the intentions for teacher leadership roles may not match the realities. Paradoxically, the confusion surrounding emerging teacher leadership roles led Wasley to conclude that the "factors that enabled the teacher leaders to be successful with their colleagues also constrained them, at once enhancing and diminishing their potential" (p. 154).

Zinn (1997) reported on a very interesting three-stage case study of teacher leadership at the elementary school level. Three issues guided Zinn's study including: conditions within the educational context that act as sources of support or barriers to teacher leaders, conditions outside the educational context that act as sources of support or barriers to teacher leaders, and the internal intellectual and psycho-social factors that motivate or impede teacher leaders. One of the key outcomes of the study was a matrix that categorized key sources of support and barriers to teacher leadership. Among the most significant sources of support were a strong network of colleagues, administrative support, and family and friends. Included among the most significant barriers to teacher leadership were insufficient time, a lack of support from teachers and administrators, and family and other commitments that conflict with the demands of teacher leadership.

Clearly, the demands of teacher leadership are many and challenging. At the same time, there are substantial barriers to achieving success in teacher leadership roles. But fortunately, there are many sources of support and means to enhance teacher leadership. The challenge can be simply stated--remove the barriers and increase the sources of support.

The Challenge Ahead

Creating the revolutionary organizational structures needed to promote the kind of teacher leadership envisioned by those at the forefront of educational restructuring will not be a simple task. Old ways die hard. Redefining roles in ways that encourage teachers to assume major responsibilities for instructional leadership is a tall order for many of us in the educational establishment. Moving away from the factory model of schooling requires no less than a major revolution in thinking that many teachers, principals, superintendents, board members, and especially legislators may not yet be prepared to embrace.

But if teacher leadership is to play a significant role in the genuine renewal of schools and schooling in this country, education professionals must expect the challenge to be difficult. They must recognize that significant social change rarely occurs suddenly and, like all meaningful change, is difficult to achieve. How long has American society been struggling to become fully integrated? To ensure equality for men and women? To combat alcohol and drug abuse? Complex structural changes on the scale and of the significance required to substantially alter the way schools do business will be no less challenging than issues relating to integration, equality, and substance abuse. Everyone must realize that real change--the kind of change discussed here--must occur first and foremost in the hearts and minds of individuals, not in the politics and policies of institutions. When enough individual hearts and minds change, then policies and practices will change with them.

Even if American educators are successful in their efforts at reconceptualizing the way schools should be organized, they still must address a number of important issues before they can realize the goal of creating significant leadership roles for teachers on a large scale. The "egalitarian ethic" that encourages educators, and the general public as well, to think of every teacher as being just like every other teacher regardless of "how experienced, how effective, or how knowledgeable" individual teachers may be remains a major obstacle to designing meaningful teacher leadership roles (Lieberman, 1988, p. 7). The isolation imposed on teachers by the way work responsibilities are divided, time schedules and work calendars are arranged, and buildings are designed continues to prevent them from active participation in the discussion of educational reform. And turf wars between bureaucratic school hierarchies and powerful teacher organizations initially spawned to protect teacher rights and privileges now stand in the way of true collaborative relationships that embrace the entire educational community.

Although these issues will not be resolved easily, the potential rewards are more than worth the effort. The end of forced teacher isolation and the building of colleagueship among teachers and between teachers and principals are achievable goals. In addition, greater recognition and enhancement of the status for teachers, a more favorable system of teacher rewards, and the building of more flexible and responsive school structures to reshape teaching as a legitimate profession can improve the work lives of teachers and encourage greater numbers of talented young people to pursue teaching as a career (Lieberman, 1988, p. 8). Perhaps most important, a realization of the potential for teacher leadership on a broad scale can truly professionalize teaching and revolutionize schooling in America.

Although a number of forces have been driving the educational establishment toward a reconceptualization of schools and schooling, the extent to which it is possible to effectively restructure American public school education may well depend primarily on educators' ability to change their conceptualization of teachers and the conditions in which they work. As it is currently structured and practiced, many thoughtful observers would not even consider teaching to be a true profession. Far too many novice teachers leave after a very short (one or two year) "trial period."

On the basis of our examination of the work of others and our own observations and discussions with hundreds of teacher leaders over the years, we have arrived at two major conclusions. First, if schools are to be restructured successfully, teachers must assume a variety of important instructional leadership responsibilities. Second, many teachers are willing to assume these responsibilities, but have not been adequately prepared in terms of the knowledge, skills, and attitudes required to function as instructional leaders. As a profession, we must find ways to help teachers develop the attitudes and gain the skills and experiences they need to lead successfully.

Without question, teachers are the best and most abundant source of leadership available for our schools. Teacher leaders remain the last best hope for significantly improving American education. If teachers fail to embrace their responsibility to provide the leadership needed in our schools, then our schools will fail. And if administrative bureaucrats do not provide the conditions and support necessary for teacher leadership to flourish, then our schools will fail. In the final analysis, the efforts of teacher leaders at the forefront of change will be only as successful as the bureaucracy *allows* them to be!

Our experience has proven to us that it is absolutely vital that teachers remake the profession and establish a culture in which classroom teachers are seen as fully empowered partners in shaping policy, creating curriculum, managing budgets, improving practice, and bringing added value toward the goal of improving education for children (Troen & Boles, 1994, p. 40).

References

Alkin, W. (1942). *The story of the eight-year study.* New York: Harper and Row.

Creighton, T. B. (1997). *Teachers as leaders: Is the principal really needed?* Paper presented at the Annual National Conference on Creating Quality Schools, Oklahoma City, OK.

Hatfield, R. C., Blackman, C., Claypool, C., & Master, F. (1987). *Extended professional roles of teacher leaders in the public schools.* Unpublished manuscript, Michigan State University, East Lansing.

Lieberman, A. (1988). Expanding the leadership team. *Educational Leadership, 45* (5), 4-8.

Lieberman, A., Saxl, E., & Miles, M. (1988). Teacher leadership: Ideology and practice. In A. Lieberman (Ed.), *Building a professional culture in schools* (pp. 148-166). New York: Teachers College Press.

Little, J. (1988). Assessing the prospects for teacher leadership. In A. Lieberman (Ed.), *Building a professional culture in schools* (pp. 78-106). New York: Teachers College Press.

National Commission on Excellence in Education (NCEE). (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: Government Printing Office.

O'Connor, K., & Boles, K. (1992, April). *Assessing the needs of teacher leaders in Massachusetts.* Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Pellicer, L. O., Anderson, L. W., Keefe, J. W., Kelley, E. A., & McCleary, L. (1990). *High school leaders and their schools: Volume II. Profiles of effectiveness.* Reston, VA: National Association of Secondary School Principals.

Senge, P. (1990). *The fifth discipline: The art of the learning organization.* New York: Doubleday.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Education Review, 57*, 1-22.

Silberman, C. (1970). *Crisis in the classroom.* NY: Basic Books.

Teachers leading the way: Voices from the national teacher forum (1998). [Available online]. http://www.ed.gov/pubs/TeachersLead/forms.html

Troen, V., & Boles, K. (1994). A time to lead. *Teacher Magazine,* pp. 40-41.

Wasley, P. (1991). *Teachers who lead: The rhetoric of reform and the realities of practice.* New York: Teachers College Press.

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Zinn, L. F. (1997). *Supports and barriers to teacher leadership: Reports of teacher leaders.* Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

2

What Evaluation Tells Us About Professional Development Programs in Mathematics and Science

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This chapter[1] presents a review of what is known from evaluation studies about the impacts of professional development programs in mathematics and science education, and their role in systemic reform. Following comparisons of program focus, structure, target population, and geographic scope, an overview of program goals is presented in terms of the following dimensions: 1) increasing teacher knowledge; 2) providing teacher renewal and the opportunity for networking; 3) increasing leadership and empowerment; 4) changing classroom practice; 5) increasing student interest and achievement; and 6) enhancing minority participation. The analysis shows that few studies have included close examination of what happens as a result of participation in professional development programs. Studies have typically focused on teacher satisfaction or other self-reported feedback. Even so, the evaluation climate has been changing, with increased emphasis being placed on evaluations that closely examine outcomes for teachers and for students, using a broader range of data gathering techniques and more robust evaluation designs. Professional development programs intended to improve teacher skills, knowledge, and practices are central to current strategies for reforming public education systems. Despite widely held beliefs that professional development programs are essential, there is little data to substantiate the impacts that such experiences make. This chapter provides an overview of what evaluation studies have told us about the efficacy of professional development as a tool for change.

Historical Background

Before the 1950s

To understand the context in which current teacher enhancement programs in science and mathematics are operating, it is useful to

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[1] This chapter is an update of Frechtling, J., Sharp, L., Carey, N., Vaden-Kiernan, N. (1995). *Teacher Enhancement Programs: A Perspective on the Last Four Decades. Rockville,* MD: Westat.

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take a brief look at changes and continuities in educational practices and priorities during the 20th century, especially since the end of World War II.

Prior to the depression era, public schooling put little emphasis on academic subjects; fewer than half of all students graduated from high school, and the number of those graduates going on to college was small. Furthermore, the majority of those who went on to the best colleges had attended private schools. For the great majority of students, and especially the masses of immigrants, most of whom were believed to be of low intelligence, the curriculum focused on "health, worthy home membership, vocation, citizenship, worthy use of leisure time and ethical character" (Kirst, 1984). A focus on academic content was absent. Instead, there was heavy public support (and federal funding) for vocational education during this period. Gradual change came about during the depression, when the lack of jobs motivated many more students to graduate from high school. The growing interest in more education suitable for the needs of all students coincided with the development of "progressive education" advocated by John Dewey and his followers, which relied on developmental theories to structure children's learning processes. According to Raizen (1993), "progressive education ... became the orthodoxy of American public schools," although it had its share of critics. And while Dewey believed that the principles of progressive education should be integrated into a strong academic curriculum, this notion did not become part of the thinking of the educational establishment in the majority of states and communities, where upper-level science and math courses were seen as "elitist" offerings. Thus, the academic component of education continued to be downgraded, and teacher training, both preservice and inservice, emphasized teaching methods and learning and behavioral theories rather than substantive academic and curriculum issues.

During this period, a parallel development was the gradual professionalization, and later unionization, of the teaching force. As the older generation of teachers (many of whom had at most a 2-year college education obtained in a teacher-training institution) were succeeded by 4-year college graduates, continuing education, which to some extent fulfills the same function as inservice training and is usually provided by academic institutions during the summer months, became a popular innovation. It exposed teachers to new knowledge and ideas, but it also subsidized the acquisition of graduate degrees by ambitious and motivated teachers. One of the earliest inservice programs was funded at Duke University, where the Duke family had specified that school teachers should be given tuition-free courses for two summers. "Since two consecutive sets of six week courses were available each summer, it was possible for teachers to satisfy two-thirds of the requirements for a masters tuition free. In 1939 and 1940, I was one of the hundreds, probably thousands of teachers who took advantage of this outstanding opportunity" (Meserve, 1989). Inservice training, whether in the form of course taking or participation in enhancement programs, continues to play an important part in furthering teachers' career opportunities to this day, whether for license renewal or promotions and salary increases.

From the 1950s to the 1980s

Between the end of World War II and the end of the cold war, the American educational system was challenged by a series of demographic, technological, political, and social developments. The diverse demands created by these developments were at times inconsistent; they also required major expenditures by state and local governments for which the federal government gradually assumed some responsibility, and they affected elementary and secondary mathematics and science instruction more than other subject areas.

Emphasis on students' academic achievement. The great increase in the demand for higher education that started with the end of World War II, when veterans attended college under the GI Bill of Rights, continued throughout this 30-year period and led to much greater emphasis on academic subjects and student achievement in high school. In earlier years, "general" or vocational education was the predominant mode in many K-12 school systems. The first initiatives to improve the academic content of the high school curriculum, especially in mathematics and science, came from industry. With the end of World War II, some influential corporate leaders, especially those at the General Electric Company (GE), began to plan for major conversions from war-time to peace-time production, which called for trained manpower in scientific and technical fields. GE officials became involved in efforts to improve the weak academic background of many high school teachers, which a review of records obtained from the New York State Department of Education had revealed. A high school teacher fellowship program was set up in 1945 at Union College, which had close ties to GE, and 40 fellows were invited to participate. Program emphasis was on academic content and lectures by prominent scientists, as well as on exposure to GE's production facilities and employment opportunities in the company (Krieghbaum & Rawson, 1969). Later, several other institutions (Case, Syracuse, Berkeley), also offered summer programs sponsored by GE. In 1952, GE launched a program at Rensselaer Polytechnic Institute for mathematics teachers, and soon programs were offered at other institutions (Purdue, Stanford) as well. When GE discontinued its summer programs for high school teachers, approximately 2,500 public and private high school teachers had participated; the total cost to GE was in excess of $1.5 million.

Westinghouse, GE's main competitor, began sponsoring a summer program for high school teachers at Massachusetts Institute and Technology (MIT), and one for guidance counselors at Carnegie Institute of Technology. Other companies also supported teacher training programs during the 1950s, including DuPont, Shell Oil, and Burroughs Adding Machines.

The emphasis on the academic content of the high school curriculum was greatly accelerated by Sputnik, the Russian space triumph, which signaled to the American public and to scientists and policymakers (especially in Congress) that the Soviet Union had equaled or perhaps outpaced America's technological leadership. It was widely believed that this had happened because the United States did not train a sufficient cadre of scientists and engineers; this in turn was partly attributed to American students' inadequate mathematics and science education. These concerns triggered the first large-scale teacher inservice programs sponsored by the National Science Foundation (NSF), the NSF institutes, which aimed at increasing teachers' scientific skills and knowledge in their fields.

From its modest beginning with a single summer institute for high school teachers in 1954, the program escalated rapidly; by 1957, over 6,500 teachers were involved, summer institutes were held in all but five states, and funding absorbed 25 percent of the total NSF budget. In 1959, NSF enlarged the program and included institutes for elementary school administrators and teachers. (Institutes for elementary administrators and teachers were discontinued in 1966.) The program continued to grow until 1965, when there were nearly 450 institutes with 21,000 high school teachers as participants. In the late sixties, the institutes reached their highest level, supporting over 35,000 participants per year; by that time, they had supported 50 percent of all secondary science and mathematics teachers (Lomask, 1975; Raizen, 1993).

The institutes were extremely popular with the Congress because funds went to every congressional district and most often to non-elite institutions, which seldom qualified for NSF research and fellowship grants. Institute funding was earmarked in the annual NSF funds appropriated by Congress. But despite this congressional support, the NSF institutes came under increased scrutiny in the seventies. Questions were raised about the efficacy of the concepts on which the institutes were modeled, with their emphasis on "top down" instruction by eminent scientists and their focus on subject matter expertise to the neglect of pedagogic technique and learning theory. There was little concern from staff about implementation of institute precepts in the school settings in which the teachers functioned, and little evidence that participation had affected teacher behavior and student learning and achievement. But there were other reasons as well, and they were probably more important than judgments about the program's effectiveness. The teacher institutes became linked to NSF's curriculum development initiatives, which became politically controversial. Furthermore, decreases in school enrollment and concerns about a coming surplus of scientists and engineers also contributed to the decision to phase out the NSF teacher institutes. By 1976, the program received almost no funding.

Changing concerns and priorities. Concerns about the quality of U.S. math and science education were temporarily eclipsed by desegregation and civil rights issues, which led to major restructuring of school systems and instructional materials. Teachers needed inservice or enhancement programs to learn to work more effectively with previously underserved students, including minorities and students with limited English proficiency. The focus shifted from secondary to elementary and middle school students. At the same time, because of the controversies and conflicts generated by the Vietnam War and a resurgence of progressive child-centered views, students and activists in urban areas demanded more relevance and individual choice (Bierlein, 1993). In response, graduation requirements were watered down or eliminated in some districts. Academic excellence took a back seat to equity issues, and specific math and science requirements were once more considered elitist and inappropriate for the large numbers of students who were unprepared to succeed in these fields. The shift in federal funding priorities contributed to the drastic reduction of NSF funding for precollege mathematics and science programs; NSF saw little reason to argue with these new priorities, although the elementary math and science curricula that had been developed earlier had proved quite successful with some of the targeted populations (Raizen, 1993).

The Call for Educational Reform in the 1980s: Excellence and Equity

Before long, the pendulum swung back again. The educational liberalism of the sixties and seventies was challenged by a growing number of critics who felt that education policymakers had neglected the issue of excellence, and who pointed to low achievement levels (as measured by the National Assessment of Educational Progress) and declines in national test scores as evidence of deterioration of the American educational system. Even more concern was generated by the results of international studies of mathematics and science achievement, particularly with respect to 13- and 14-year-olds, which showed American students with lower achievement scores than students in most of the other countries included in the comparisons (NSF, 1992; NCES, 1996). Given the growing concern about U.S. competitiveness in world markets, these data were especially disturbing. The renewed concern with educational quality and academic achievement triggered a spate of calls for reform by policymakers, scientists, educators, and special task forces.[2]

Simultaneously, various groups of educators and policymakers began to work on the development of new standards for mathematics and science teaching and learning.

Educational Reform in the 1990s and Implications for Professional Development

Superficially, the new call for reform might suggest a return to the academic priorities of an earlier period. However, this would be a misreading of what the proponents of the reform movement in academe, professional organizations, foundations, and federal, state, and local government bodies have crafted. Rather, reform combines the call for academic excellence with a commitment to equity; it also seeks to impart to all students knowledge and skills appropriate for successful participation as adults in a society increasingly driven by science and technology. All K-12 students regardless of gender and ethnic or linguistic background should acquire mathematical power and scientific literacy that will enable them to function successfully in today's world of rapid technological changes. To achieve this goal will require major changes in curriculum, instructional practices (many of them reminiscent of the tenets of progressive education), and testing or learning assessment practices. Given the decentralized character of the American educational system, the task is a formidable one. The simultaneous introduction of these changes in individual schools as well as in state and local administrative and supervisory bodies ("systemic change") is believed to be the key to the success of reform.

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[2] Probably most influential was *A Nation at Risk*, the 1983 Report by the National Commission on Excellence in Education. Other important documents were *Science and Mathematics in the Schools*, National Academy of Science, 1982; *Report of the Twentieth Century Fund Task Force on Federal Elementary and Secondary Education* (1983); and *National Education Goals*, adopted by the membership of the National Governors' Association in 1990.

At present, science and mathematics education are the first targets of systemic reform, and specific goals and methods for these fields have been delineated. Systemic reform

- Involves all segments of a school system, from kindergarten through the 12th grade, with the elementary school years seen as especially important for the acquisition of mathematical power and scientific literacy by all students.
- Includes new standards that have been adopted for mathematics and science education.
- Requires ongoing professional development for teachers directed at leading students to think, reason, and make discoveries; promoting group work; and working with heterogeneous classrooms, rather than emphasizing lectures, textbooks, memorization of facts, or grouping of students by ability levels.[3]

Current Programs

The term "professional development" as used in the 1990s is similar to the term "school reform." Although apparently simple and easy to understand, it is a single label that covers a wide variety of services and experiences offered to teaching professionals. Today's professional development programs can be described in terms of two general dimensions: their focus and their structure.

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[3] See especially *Professional Standards for Teaching Mathematics*, published by the National Council of Teachers of Mathematics, Reston, VA, in March 1991, and *National Science Education Standards* (1996), National Research Council, Washington, DC.

Focus

"Focus" as used here means the content of the professional development program or the types of knowledge and skills that are being taught. The focus of today's programs varies along two dimensions: whether the purpose is to provide direct training or to build the capacity to provide training; and whether the skills and knowledge imparted primarily address pedagogy, content, or some combination of both.

Let us look first at the question of direct training versus capacity building. As shown by our brief review of the history of professional development programs, such programs traditionally have emphasized the direct training approach, modeling inservice strategies on the preservice model of knowledge enhancement. Thus, teachers have been brought together to learn about new pedagogies, new findings in their field, new tools for education, such as computers, or new policies in their district or state. The immediate goal of these programs is to have the participants hear about and integrate information on the topic covered into their own practice. Many argue, however, that this approach is not optimal, given the numbers of teachers who need to be reached. Instead, what is believed to be needed is building local capacity to provide ongoing training. Proponents of the capacity-building approach argue that the needs for support are so great that unless internal structures that can provide professional development are built or strengthened, the continuing needs of teachers cannot be met.

The second question regarding focus concerns what the learning is about. Is the focus of the professional development on how to teach, what to teach, or some combination of both? Programs stressing content see the role of professional development efforts as that of providing teachers with enhanced or advanced knowledge in their fields. This may include learning about new equipment that can be used in laboratories or other technological innovations that can support learning and promote students' interest. This information may be offered through classroom or workshop experiences or through research immersions in applied settings. Some of these efforts may be university based; others are placed in or closely linked with places where practicing scientists (or mathematicians or engineers) work. Many of these efforts, especially those in applied settings, also provide experience in "doing science" as part of a scientific research team.

Experiences that focus on pedagogy stress the need to reform the teaching/learning interactions, with the present emphasis on the constructivist approach Such programs typically are designed to provide teachers with skills to use hands-on, inquiry-based instruction, to connect the students' learning experiences to real-world tasks and careers, and to be a coach or facilitator rather than a lecturer. Depth is stressed over breadth, problem solving over memorizing facts.

Over the last decade there has been a pendulum swing between the content and pedagogical focus. Today, the need for improvements in both arenas is recognized, with international comparative studies such as the Third International Mathematics and Science Survey (TIMSS) showing teachers in the United States to be needing support in both areas (NCES, 1996).

Structure

"Structure" as used here means the approach to planning and delivering teacher enhancement programs. There are two schools of thought that coexist today with regard to the structure of teacher enhancement programs: although an oversimplification, the contrast between them is the extent to which the experiences are expert-driven or teacher-driven. (This contrast shares many characteristics with the top-down, bottom-up debate that continues to rage with regard to school reform.) At the extreme, the expert-driven model involves experiences that are directed by experts (in mathematics and science, these experts are frequently practicing scientists in academic or applied settings) who share their knowledge, work environment, and work experiences with teachers who come to learn with and from them. Lieberman (1995) characterizes this method as the conventional approach, which defines staff development as "a transferable package of knowledge to be distributed to teachers in bite-sized pieces" (p. 592).

At the other extreme are teacher-driven experiences, which aim as much at changing culture as gaining new skills and knowledge. These tend to be of relatively long duration and to embed the development activities in the teachers' place of work, the school setting itself. Proponents of the teacher-driven approach see schools as learning organizations and believe real change requires collective problem solving, practice, and creating a culture of inquiry (Lieberman, 1995).

In addition to philosophy, characteristics that distinguish these two approaches, and may even vary within them, include intensity, target population, and geographic scope.

Intensity. Professional development activities range from short, single-shot experiences to multi-year programs. Some teacher enhancement programs are short-term workshops or inservice days in which a particular technique is explained or a new policy introduced. Others are longer term summer workshops or mentorships that are several weeks in duration and may include year-round followup activities. Still others are based on a multi-year format, with teachers graduating through stages. These may include alternating cycles of learning and application across a 2- to 3-year period. While there appears to be general agreement that the ongoing, more intensive type of professional training is preferable, extended professional development is not always the model used.

Target population. Programs vary in the extent to which they target individual participants versus teams of participants from a single school or a site. In the latter case, the teams may include several teachers from the school, may be more heterogeneous and involve teaching, administrative, and even community personnel, or may serve multiple individuals from the same site over consecutive training sessions. It has been argued (Lieberman, 1995) that the school-based approach has many advantages—a critical mass of trained personnel, a more supportive environment for change, a set of services that are more closely aligned with the needs of the school. Others feel that even changing one teacher can make a difference, and that bringing together teachers from different schools and environments can be both energizing and renewing.

Geographic scope. Programs vary in whether they are targeted at the local, regional, or national level. While teacher-directed programs are almost always local, those based on the expert model or those that involve research experiences can be local, regional, or national in scope. It should be noted that one advantage of the more local model is that the potential for followup and continued support during the time following training is much greater. While some accommodations can be made for geographic disbursement, such as newsletters or Listservs, the potential for continued interaction and support is simply much greater where the participants come from areas that are close to one another.

Current Goals of Professional Development Programs

Programs also vary in terms of their goals—especially the extent to which the teacher rather than the student is the primary target of program impact. While in general terms all programs acknowledge that the goal of professional development is to provide improved instruction that will contribute to improved student achievement, many have traditionally considered student achievement to be too distal or affected by too many different factors. Changing or assisting teachers is seen as an end that is important, and sufficient, in and of itself. Potential goals follow:

Increasing teacher knowledge. A primary goal in professional development continues to be increasing teacher knowledge. One reason for the need to increase teacher knowledge is that mathematics and science teachers, especially those who teach elementary students, often receive inadequate preparation in these subjects in their undergraduate education. Because of inadequate preparation, many teachers do not feel confident about their teaching abilities in mathematics and science and often do not enjoy teaching these subjects. Thus, many programs seek to increase teachers' confidence by giving them the opportunity to understand more about math or science and more about methods for teaching the subjects.

Another reason for increasing teacher knowledge is that teachers today are expected to be knowledgeable and capable in areas that they may not have dealt with as undergraduates, such as computers, environmental issues, and new technologies. Teachers today also need help in assuming roles that are nontraditional for them, such as developing assessment capabilities and becoming leaders in their schools. Given changes in technology, curriculum, and teaching methods, many argue that it is not feasible to completely prepare a preservice teacher for a lifetime of teaching (e.g., Meserve, 1989).

Providing teacher renewal and the opportunity for networking. Another important aspect of the current reform movement is renewal and the opportunity for continued networking. Although many professional development programs do not cite networking as a goal, many stress renewal and have networking components. Networking with others is often used to decrease teacher isolation and increase professionalism by increased opportunities for teachers to interact with one another and other professionals to share their experiences and knowledge. A great deal of networking takes place through contacts with others in the teacher enhancement programs and through professional development activities, such as attending conferences. Some programs also support and encourage teachers to network through computers. E-mail computer networking is one of the major followup activities used by professional development summer institutes that serve participants from across the nation. Through these contacts, teachers have the opportunity to learn about new developments in their field, to keep up with other program participants and mentors, and to share their experiences.

Increasing leadership and empowerment. Many programs emphasize the development of teacher leaders. Teacher leaders are very useful in reaching out to and teaching other teachers. Programs that develop teacher leaders can indirectly reach many more teachers when teacher leaders share their knowledge with others.

Professional development programs also may serve to empower teachers. In addition to increasing teacher empowerment through leadership development, many current programs emphasize teacher empowerment through their methods of teaching teachers. An assumption in many of the new programs is that teachers should have direction and control over their own learning and professional development (Shavelson, Copeland, Baxter, Decker, & Ruiz-Primo, 1994). Instead of top-down programs in which teachers passively receive knowledge, the emphasis today is on the active participation of teachers in their own learning. When teachers have more ownership of their education, they are expected to be more invested in the changes brought about by it.

Changing classroom practice. Changing classroom instruction is another major goal of professional development programs. Most programs help teachers in some way to apply what they learned in the program to the classroom, for example, by giving teachers materials or equipment for classroom activities or having teachers write detailed plans for how they intend to use what they learned in their classroom. Some programs focus on this aspect more directly and give teachers the opportunity to field test what they have learned with students in the program or give teachers coaching or feedback in the use of new instructional tools or materials in their home classrooms.

Increasing student interest and achievement. An underlying goal of professional development programs is to increase students' interest in mathematics or science and to improve achievement. In some programs, this is often not an explicitly stated goal; however, through improved curricula and improved teacher knowledge and teaching methods, it is expected that students will benefit from these improvements. Programs aim both at providing instruction that will help students become more "world class" performers and at creating a more scientifically literate society.

Enhancing minority participation. An even more indirect goal of programs is to increase participation of minorities in science and mathematics. Some professional development programs are designed to attract more students who are members of groups that do not usually pursue careers in science or mathematics, such as minorities, females, and persons with physical disabilities. Some programs have required that teachers who are part of minority groups be involved, while others have developed models for inservice that are particularly encouraging to the development of leaders among underrepresented groups. The idea behind some of these efforts is that teacher leaders from underrepresented groups will encourage students from these same groups to become more interested in mathematics and science.

Evaluation Findings

It is clear that professional development programs are popular and valued widely, but what do we really know about their impacts? A report by the General Accounting Office (GAO) asserts that the answer is really very little. The 1994 GAO report on the Department of Energy's Precollege Math and Science Education efforts was highly critical, chastising the Department for both its failure to conduct sound evaluations and the lack of data linking participation in professional development programs to one specific outcome, student achievement (GAO, 1994). GAO supported its 1994 conclusions about the lack of efficacy of professional development programs by citing studies previously reviewed in its own 1984 report (GAO, 1984). While there are some flaws that can be cited with regard to this report (for example, the contention that there is stronger evidence on the efficacy of curriculum and systemic change efforts than there is on professional development, and their sole reliance on student outcomes as a measure of program success), the GAO report does sound an alarm, identifying a lack of comprehensive and methodologically sound evaluations.

While this paucity of evaluation literature is disappointing, it is not surprising given the limited resources that have been devoted to evaluation of federal mathematics and science programs in general. As noted in the report of the Expert Panel for the Review of Federal Education Programs in Science, Mathematics, Engineering, and Technology (SMET), "the impact of current Federal efforts in SMET education remains unclear....Federal expenditures are being made with too little overall planning and with inadequate evaluation." In fact, for a majority of federally funded SMET education programs, no evaluation information is available at all (Committee on Education and Human Resources, 1993). Furthermore, only recently has there been a clear mandate from the federal government that all federal agencies evaluate their SMET education programs and that these evaluations be "results-oriented." Snyder and Frechtling (1997) writing about the changing demands for evaluation of professional development programs summed up the change as follows:

> *Recently the demand for evaluation data has increased, changing in both focus and form. Instead of solely targeting questions related to perceptions and descriptions of program characteristics, evaluators are being asked to address questions related to outcomes for schools, classrooms, and students. Instead of relying primarily on self-reports of program outcomes, evaluators are being asked to incorporate methodologies that provide harder data, preferably data from multiple data sources.* (p. 34)

In this section, we present a review of evaluations of teacher enhancement programs using both published and unpublished materials. Our review generally corroborates the GAO's conclusions. Further, they show that few evaluations have even addressed the question of the linkage between participation in a teacher enhancement experience and student outcomes. Typically, these evaluations have looked at the following outcomes:

- Were the participants satisfied with the training experience?
- Did the participants acquire new knowledge and teaching skills?
- Were the new skills transferred to classroom practice?
- Did the experience have a positive impact on teachers' feelings of professional renewal and career satisfaction?
- Do teachers feel more empowered and able to take on leadership roles in their home schools and to act as disseminators of information?
- Have students' attitudes toward math and science and their achievement in these areas improved as a result of teachers' participation in programs?

As might be predicted, the majority of studies have looked at the first two outcomes, with fewer addressing the impacts further down the list. To illustrate the status of the evaluation literature, selected studies and their outcomes are presented.

Participant Satisfaction

A high degree of participant satisfaction is one of the most prevalent findings concerning teacher enhancement programs. Many programs report that through either exit or followup surveys, participants have indicated that the program was a satisfying and positive experience for them.

In general, evaluation studies report these findings in two ways. First, they report respondents' answers to Likert-like scales in which they are asked to rate the degree to which they were satisfied with the program. For example, in the Department of Energy's followup survey to the Teacher Research Associates (TRAC) program (Vivio & Stevenson, 1992), participants were asked in the exit survey to rate their overall satisfaction with the program. On a scale from 1 (very dissatisfied) to 10 (very satisfied), more than 70 percent responded with a 9 or 10, with an average rating of 9. In the evaluation of the Great Starts Mathematics Approach (Jarvis & Blank, 1989), 90 percent of the participants said that the program had a major impact in influencing their understanding of ways to teach math.

Program evaluations also report comments made by program participants to illustrate the kinds of reactions received to workshops. Participants in the Eisenhower-funded program Implementing the

National Council for Teachers of Mathematics Standards for School Mathematics for the 21st Century (Kroll, 1990) said that the workshops "excited and inspired" them. The report on DOE's TRAC program (Vivio & Stevenson, 1992) included quotes from participants such as the following: "It was very refreshing." "It gave us a sense of self-worth." "My thoughts are valuable to someone." "Someone is going to listen to me." These are typical responses of teachers about their teacher enhancement experiences.

Teachers in general appear to feel very positively about their experiences in teacher enhancement programs. While these reactions are often reported as overall satisfaction, participants frequently are asked to rate their satisfaction with specific aspects of the programs. These outcomes are discussed more fully in the sections that follow.

New Skills and Teacher Techniques

Most studies provide evidence that teachers feel they have gained knowledge or increased their skills through teacher enhancement programs. There are fewer studies, however, that provide evidence of increased teacher knowledge using measures other than self-report.

With few exceptions, participants in teacher enhancement programs rated themselves as having increased their knowledge of science and mathematics, and of ways to teach the subjects, as a result of their experiences. For the most part, these data on teacher ratings, collected at the conclusion of the teacher enhancement program, provide short-term assessments. For example, Taagepera, Miller, and Benesi (1985) reported that 88 percent of the 100 teachers in the University of California-Irvine (UCI) Summer Science Institute agreed that courses were increasing their understanding of basic concepts in science. No evidence beyond that of self-report was provided.

A few studies have included standardized measures of gains in teacher knowledge. Some of these studies, however, are plagued by measurement difficulties. For example, Horak, Blecha, and Enz (1982) found no increase in teacher science knowledge, but they used such an easy test that many teachers scored 100 percent on both the pre- and post-program tests. When measures are adequate, however, standardized tests can show significant increases in teacher knowledge. In one report, Weiss, Boyd, and Hessling (1990) cite a study in which participants improved from a median score at the 62nd percentile on the National Science Teachers Association/American Association of Physics Teachers (NSTA/AAPT) high school physics test to a median score at the 85th percentile during the second summer, to a median at the 99th percentile by the third summer. In another study (Rhoton, Field, & Prather, 1992), there were statistically significant gains in teachers' instructional and curricular skills and content mastery as measured by pre- and post-program tests.

In summary, most evaluations report that teachers feel better about their content knowledge and teaching skills as a result of teacher enhancement programs. Increased confidence about their subject matter knowledge can lead to a decrease in anxiety about teaching math and science. Although most of the evaluations are based on teachers' self-report, increased teacher confidence about knowledge and skills has been considered an important contributor to adaptive and effective teacher behaviors in the classroom.

Transfer of Skills to Classroom Practice

Teachers report a number of different ways in which they have applied their lessons to practice. However, there has been limited corroboration of the actual implementation of changes by evaluators.

Marable (1990) reported that teachers indicated that they developed curriculum materials for use in their classrooms. Boser and associates (1988) found that teachers reported a significant increase in time devoted to lab activities in classes as a result of the Science Teachers Research Involvement for Vital Education (STRIVE) program. Finally, Hadfield (1992) found in post-inservice questionnaires administered after teachers had returned to their home schools that teachers reported spending more time teaching math, using materials from the workshop, and getting positive responses from students about instruction.

One study (Eash, Hagar, & Weigrecht, 1989) did attempt to assess classroom changes using measures other than self-report. The researchers used students as observers of teachers to support their self-reports of changes. Specifically, they found that student reports verified participant teachers' claims of changes in classroom approach in the following activities: requiring students to plan and organize cooperative group projects; including in classroom work applications of science concepts in industry; stressing the importance of science in society; increasing student interest in science as a career; increasing the use of questioning during class; and introducing new materials into the regular curriculum. In another study (Carpenter, Fennema, Peterson, Chiang, & Loef, 1989), classroom observations were included in the evaluation. These observations indicated that even though specific instruction patterns were not prescribed in the teacher enhancement workshop, the teachers who participated in the training activities spent more time in the classroom talking about problems and discussing alternative solutions than did teachers of control classes.

Two recent efforts have begun to provide more robust evidence in this area. The first is a formative study being conducted by Iris Weiss and Horizon Research, Inc. With funding from NSF, Weiss, Montgomery, Ridgway, and Bond (1998) are documenting the implementation of what are called local systemic change (LSC) projects. The goal of the LSC program is to improve the teaching of science, mathematics, and technology by focusing on the professional development of teachers within whole schools or school districts. Each targeted teacher in a K-8 project is to participate in a minimum of 100 hours of professional development; for projects targeting teaching in grades 6-12, the minimum is 130 hours over the course of the project. In addition to its focus on involving all teachers in a jurisdiction, the LSC initiative is distinguished from previous professional development efforts by its emphasis on preparing teachers to implement designated exemplary mathematics and science instructional materials in their classrooms (Weiss et al., 1998). This study addressed the following issues:

- What is the overall quality of the LSC professional development activities?
- What is the extent of school and teacher involvement in LSC activities?
- What is the impact of the LSC professional development on teacher preparedness, attitudes, and beliefs about mathematics and science teaching and learning?
- What is the impact of the LSC professional development on classroom practices in mathematics and science?
- To what extent are school and district contexts becoming more supportive of the LSC vision for exemplary mathematics and science education?
- What is the extent of institutionalization of high-quality professional development systems in the LSC districts?

This study provides one of the most comprehensive examinations of the implementation of such programs conducted to date.

A second study, the Multi-Agency Study of Teacher Enhancement Programs (Frechtling, 1997), documented the classroom impact of professional development programs funded by five federal agencies. Programs included in this study were believed to represent "best practices" in professional development by the agencies supporting them. The study included projects that attempted to enhance teachers' knowledge and skills through both direct modeling and immersion in the research experience. The study combined several data collection techniques: site visitations to the professional development programs themselves, teacher interviews, teacher surveys, and site visits with a small sample of program participations to observe instruction and interview colleagues. The study found that both types of professional development programs appeared to change teachers' classroom practice.[4] Reported changes were greater at the elementary than the senior high school level. Both teachers who initially reported using standards-based practices and those that did not appeared to gain from their experiences. One important finding from this study was that the context of the school or district is very important. Teachers who worked in more reform-oriented environments showed higher levels of implementation of practices aligned with standards-based instruction than those who came from less supportive environments.

Impact on Renewal and Career Satisfaction

Many advocates of teacher inservice mention that teachers see a sense of renewal and increased connection to their field and profession as an important benefit of these programs. Teachers place strong value on the opportunity to share ideas and teaching techniques that these programs provide.

Jarvis and Blank (1989) report that the comment most often made about the program concerned the personal and professional benefits obtained from exchanging and sharing ideas with one another. Taagepera, Miller, and Benesi (1985) indicated that teacher contact with professors in the program was a critical component of the institute's success. This contact resulted in future collaborative efforts, such as a Saturdays for Science program and the NSF-sponsored UCI Science and Math Mentor Teacher Program. Lombard, Konicek, and Schultz (1985) reported that all participants in the Science

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[4] The sample of professional development programs that used primarily a research approach was too small to draw firm conclusions about their relative effectiveness.

Teaching and Development of Reasoning workshops indicated that one important value of the workshops was the opportunity to meet together and discuss their experiences and ideas. One program, The Urban Mathematics Collaborative (Heck, Webb, & Martin, 1994), was based on the assumption that teacher networking is an inherent part of the collaborative effort because it "reduces teachers' sense of isolation, encourages professional enthusiasm and innovation in teaching, and exposes teachers to new developments and trends in mathematics and instruction." Finally, Armstrong (1987) reported that participants believed that the best aspect of the Leadership Institute was the opportunity for sharing ideas with colleagues.

Teachers frequently report that professional development experiences influenced their feelings of confidence about teaching math and science and their sense of satisfaction about their career choice. Weir (1988) reported that participants in a month-long summer science institute felt more confident about teaching science to children, and that they subsequently made more time for science in their teaching, "no matter what." Other programs, such as NSF-sponsored programs that took place on college campuses during the summer as well as during the school year (Orton. 1980), have reported that an outcome of the program was an increase in participants' going on for master's degrees, a sign of renewed motivation and a desire for advancement. Teachers also demonstrate a sense of renewal through taking on new leadership roles as teachers, thereby advancing their careers into positions such as mentor teachers and curriculum specialists.

Impact on Leadership and Dissemination

Another bright spot in professional development programs has been their effect on teacher leadership and empowerment. In fact, one fundamental goal of these projects has been to develop cadres of teachers who will take the lead in promoting changes in math and science education.

In the San Francisco Math Leadership Project (Armstrong, 1987), there was a dramatic increase in teachers' participation in professional associations, and participants saw themselves as emerging as math leaders in their schools. Kroll (1990) reported that workshop participants shared a great deal about their experiences with other teachers in their home schools who had not attended the workshop. Leadership was also evidenced at faculty meetings, with participants acting as recruiters, trainers, and support personnel for the project in the future. Henderson and Brown (1987) reported that the Monterey Bay Area Mathematics Project resulted in an increase in participation in professional development activities. Project participants also conducted inservice sessions for other teachers. Finally, Garner-Gilchrist (1993) stated that Mathematics Institute Program participants conducted workshops in their respective schools following the institute.

The evidence of teacher leadership and empowerment illustrates how professional development programs can create a ripple effect that reaches beyond the influence on actual participants. Participants themselves became proponents of positive change. However, this ripple effect too often fails to occur and evidence suggests that explicit training or support may be needed (Frechtling, 1997).

Student Outcomes

In general, evaluations of teacher enhancement programs have rarely produced credible evidence of positive student outcomes, particularly in the area of student achievement. This is because most evaluations have surveyed teachers who can only report their impressions of changes in students' achievement or attitudes. Further, the adequacy of existing measures of achievement in mathematics and science have been strongly questioned, and more acceptable ones are only in the early developmental stages. Nevertheless, a small number of studies have addressed the impact of teacher enhancement programs on students.

One study in particular stands out. Using pre- and post-program test measures of student achievement, Rhoton, Field, and Prather (1992) found statistically significant gains in the performance of students whose teachers had participated in an NSF Science Education Leadership Institute. It should be noted that this project was a long-term intervention and included the participation of the school principal, and the two factors made this professional development program fit into a larger systemic reform effort. Eash, et al., (1989) also used pre- and post-test measures administered to students in classes taught by teachers who had participated in an NSF teacher enhancement workshop. Results indicated that these students demonstrated improved attitudes toward science education and greater academic achievement when compared to students taught by teachers who had not participated in the workshop.

Another evaluation (Madsen & Lanier, 1992) used tests, written work, and verbal comments to measure student outcomes after teachers had participated in an intensive staff development program. The Support Teacher Program included updating teachers' knowledge about current research on teaching and learning mathematics and working with other professionals in a peer support program. At the end of one year, student results indicated a more positive attitude towards mathematics, an improved ability to solve problems, and an increased conceptual understanding of mathematics. Finally, Carpenter et al. (1989) reported that students in classes where teachers had received training in "cognitively-guided instruction" performed better on complex addition and subtraction and problem-solving activities than students in control group classes.

However, a multi-year study by Stallings and Krasavage (1987) raises some questions about whether or not such changes may be highly transitory. Stallings and Krasavage reported that professional development based on the Madeline Hunter model led to changes in teacher practices, student engagement, and achievement during the first two years of an intensively supported follow-through program. In the third year, when assistance to teachers was removed, both instructional fidelity and student performance declined.

Other than these studies, most evaluations either ignore student achievement or provide unconvincing and often anecdotal teacher reports of positive student outcomes, relying instead on self-report. A large-scale evaluation of NSF Teacher Enhancement programs (Abt Associates, 1993) also found that teachers report significant gains in students' enthusiasm and achievement in science. However, because these findings are based on self-report, they provide unconvincing evidence of real gains in student performance.

Two studies currently in their initial stages are attempting to take a closer look at impacts on student outcomes. In its beginning stages is a study of Summer Work Experience Programs for Teachers (SWEPTs) on student achievement, teachers classroom practices, and teacher leadership.[5] SWEPTs provide research experiences for teachers in both industry and research settings. The experiences may cover one or more summers, with some kind of contact and support frequently continuing throughout the school year. This study will examine the effects of eight different programs located across the United States using a target population of high school teachers and their students. The same teachers will be followed over two years time, and their behaviors and their students' learning will be compared to that of a control group.

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[5] This study is supported by the National Science Foundation. It is being directed by Dr. Sam Silverstein at Columbia University.

The second study is a multifaceted study of the Eisenhower Professional Development Program. The evaluation, supported by the Department of Education, is designed to provide both indepth description of the services provided through these funds and an examination of what has been learned about their impacts on student learning. Initial findings from this study are found in Birman, Reeve, and Sattler (1998).

Conclusion

Taken together, what do these evaluations tell us about the impact of professional development programs? The picture is clearly mixed, with evidence that can both give comfort to supporters and fuel the concern of critics. Despite the reliance on self-report, these evaluation findings provide substantial support for the benefits of professional development programs, at least where goals such as new knowledge, renewal, and professional leadership are concerned. The number of studies that report positive impacts in these areas suggests that participation in teacher enhancement programs makes teachers feel better about themselves, their profession, and their ability to be effective in their roles. Results with regard to classroom practice are less solid, but appear to be in the right direction. Teachers report using what they have learned, both in terms of content and process.

Support for the impact of professional development programs on student outcomes is, however, less convincing, given the evidence that we have been able to locate. Most studies either do not address student outcomes or provide indirect evidence that cannot be rigorously evaluated.[6] This lack of evidence should not be considered surprising, given the difficulty of establishing such linkages and the relatively insignificant amount of funding that has been allocated to most evaluation efforts. The situation is similar with regard to teacher leadership and dissemination of what is learned through professional development. What is needed is a well-designed, longitudinal effort that can document changes (or lack of changes) in teacher skills, teacher classroom behaviors, teacher leadership, and student attitudes and achievement over time. Such a study must look not only at the contribution of the professional development experience, but also at how the learning environment—the school and the classroom—is structured to support and reinforce the changes that need to take place. It is unlikely, however, that even the best designed study will show that the teacher enhancement and *nothing else* has caused any changes that might be found. Educators today see professional development as a major component of reform efforts, not as a stand-alone treatment. Studies should be designed to reflect the logic of this model and examine how professional development contributes to the success of the overall effort.

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[6] It should be pointed out, however, that changing student outcomes has not always been the goal of professional development programs. Often, they have been designed to change teacher behaviors.

References

Abt Associates, Inc. (1993). *A study of NSF teacher enhancement programs (TE) participants and principal investigators: 1984-89.* Washington, DC: National Science Foundation.

Armstrong, P. (1987). *Making math leaders: The San Francisco math leadership project.* ERIC Document No. 289-715.

Bierlein, L.A. (1993). *Controversial issues in educational policy.* Newbury Park, CA: Sage Publications.

Birman, B.F., Reeve, A.L., and Sattler, C.L. (1998). *The Eisenhower Professional Development Program: Emerging Themes from Six Districts.* Washington, DC: U.S. Department of Education.

Boser, J.A., Faires, C., Slawson, W., & Stevenson, W. (1988). *The effect of active research involvement on secondary science and mathematics teachers.* ERIC Document No. 303-338.

Carpenter, T.P., Fennema, G., Peterson, P., Chiang, C., & Loef, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal*, 26(4), 499-531.

Eash, M.J., Hagar, W., and Weigrecht, W. (1989). *Determining outcomes for evaluation of a National Science Foundation workshop.* ERIC Document No. 312-315.

Expert Panel for the Review of Federal Education Programs in Science, Mathematics, Engineering, and Technology. (1993). *The Federal investment in science, mathematics, engineering, and technology education: Where now? What next?* Alexandria, VA: National Science Foundation.

Frechtling, J. (1997). *Best practice in action: Final report of the multi-agency study of teacher enhancement programs.* Arlington, VA: National Science Foundation.

Garner-Gilchrist, C. (1993). Mathematics institute: An inservice program for training elementary school teachers. *Action in Teacher Education*, 15(3), 56-60.

General Accounting Office (GAO). (1984). *New directions for federal programs to aid mathematics and science teaching.* Washington, DC: Author. GAO/PEMD-84-5.

General Accounting Office (GAO). (1994). *Precollege math and science education. Department of Energy's precollege program managed ineffectively.* Washington, DC: Author. GAO/HEHS-94-208.

Hadfield, O.D. (1992). Improving elementary teacher performance and confidence in mathematics: A successful rural small school inservice. *Journal of Rural and Small Schools*, 5(2), 32-37.

Heck, D.J., Webb, N.L., and Martin, W. (1994). *Case study of Urban Mathematics Collaborative: Status report.* Madison, WI: Wisconsin Center for Education Research, University of Wisconsin-Madison.

Henderson, R.W., and Brown, N. (1987). *The Monterey Bay Area mathematics project: First year evaluation.* ERIC Document No. 295-782.

Horak, W.J., Blecha, M.K., and Enz, J. (1982). *An in-service program for elementary teachers: Components, instructional procedures, and evaluation.* ERIC Document No. 216-882.

Jarvis, C.H., and Blank, B.B. (1989). *Great starts mathematics approach 1987-88.* ERIC Document No. 316-399.

Kirst, M.W. (1984). *Who controls our schools? American values in conflict.* New York: Freeman.

Krieghbaum, H., and Rawson, H. (1969). *An investment in knowledge. The first dozen years of the National Science Foundation's summer institute programs to improve secondary school science and mathematics teaching 1954-1965.* New York: New York University Press.

Kroll, D.L. (1990). *Implementing the NCTM standards for school mathematics for the 21st century.* Indiana State Commission for Higher Education, Indianapolis. ERIC Document No. 325-389.

Lieberman, A. (1995). Practices that support teacher development. Transforming conceptions of professional learning. *Phi Delta Kappan*, 76(8), 591-596.

Lomask, M. (1975). *A minor miracle: An informal history of the National Science Foundation.* Washington, DC: National Science Foundation.

Lombard, A.S., Konicek, R.D., and Schultz, K. (1985). Description and evaluation of an inservice model for implementation of a learning cycle approach in the secondary science classroom. *Science Education, 69*(4), 491-500.

Madsen, A.L., and Lanier, P.E. (1992). *Improving mathematics instruction through the role of the support teacher.* ERIC Document No. 353-128.

Marable, P. (1990). *Focusing on teachers: ESEA Title II mathematics and science.* ERIC Document No. 325-520.

Meserve, B.F. (1989). Looking ahead in teachers' preparation: A personal perspective on NCTM-MAA Cooperation. *Mathematics Teacher*, 82(7), 564-570.

National Science Foundation. (1993). *Indicators of science and mathematics education 1992*, [Larry E. Suter, Ed.]. Washington, DC: Author. NSF 93-95.

Orton, W.R. (1980). Report of a four year statewide mathematics education project. *School Science and Mathematics*, 80(4), 309-16.

Raizen, S. (1993). *Three decades of science education reform in the United States*. Washington, DC: The National Center for Improving Science Education.

Rhoton, J., Field, M.H., and Prather, J.P. (1992). An alternative to the elementary school science specialist. *Journal of Elementary Science Education*, 4 (1), 14-25.

Rigden, D.W. (1994). *Improving science, mathematics, and technology education: Opportunities for business support*. (Occasional Paper No. 2). Council for Aid to Education.

Shavelson, R.J., Copeland, W.D., Baxter, G.P., Decker, D.L., and Ruiz-Primo, M.A. (1994). In-service education models for enhancing the teaching of science. In S.J. Fitzsimmons and L.C. Kerpelman (Eds.), *Teacher enhancement for elementary and secondary science and mathematics: Status, issues, and problems*, 5-1-5-45. Washington, DC: Division of Research, Evaluation and Dissemination, National Science Foundation.

Snyder, S., and Frechtling, J. (1997). The need for better evaluation of professional development programs. In *The fifth National Evaluation Institute: Synthesis and reflections*. Rockville, MD: Westat.

Stallings, J., and Krasavage, E. (1987). Program implementation and student achievement in a four-year Madeline Hunter follow-through project. *The Elementary School Journal*, 87(2), 118-138.

Taagepera, M., Miller, G.E., and Benesi, A.J. (1985). The UCI summer science institute. *Journal of Chemical Education*, 64(3), 234-235.

U.S. Department of Education, National Center for Education Statistics. (1996). *Pursuing excellence*, NCES 97-198. Washington, DC: U.S. Government Printing Office.

Vivio, F.M., and Stevenson, W. (1992). *U.S. Department of Energy teacher research associates program: Profile and survey of 1990-1991 participants*. Washington, DC: U.S. Department of Energy.

Weir, E.A. (1988). *Breaking down barriers to teaching primary science: Did a summer science institute help*? (ERIC Document Reproduction Service No. ED 292-686.)

Weiss, I.R., Boyd, S.E., and Hessling, P.A. (1990). *A look at exemplary NSF teacher enhancement projects*. Chapel Hill, NC: Horizon Research, Inc.

Weiss, I.R., Montgomery, D.L., Ridgway, C.L., and Bond, S.L. (1998). *Highlights of the local systemic change through teacher enhancement: Year three cross-site report*. Chapel Hill, NC: Horizon Research, Inc.

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Findings from the Multi-Agency Study of Teacher Enhancement Programs

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This chapter[1] presents the results for the Multi-Agency Study of Teacher Enhancement Programs, a study of professional development programs believed to represent best practices in professional development for science teachers. Working through an interagency government task force coordinated by the National Science Foundation (NSF), representatives from six groups, the Departments of Energy, Education, Health and Human Services, the National Aeronautics and Space Administration, NSF, and the Smithsonian Institution conducted the study. The evaluation was designed to document the teaching practices promoted in the selected programs and to examine the impacts of the programs in terms of: 1) effects on classroom practice, 2) differences in effects on classroom practice by type of program, 3) effects on teacher leadership and dissemination of findings, and 4) the importance of supports at the district and school levels. Programs selected were expected to meet most of the following criteria: 1) an instructional approach that emphasizes hands-on/minds-on activities; 2) a standards-based approach that aligns curriculum, instruction, and assessment with local, state, and national standards or frameworks; 3) development activities that extend over time, including followup when participants return to their schools; and 4) direct involvement of participants with the scientific process. Additional considerations governing selection were stability, inclusion of teachers who are themselves from traditionally underrepresented populations, and inclusion of programs that were carried out within a systemic reform context Thirty four programs were included in the study, which was divided into three phases: program documentation and description, a mail survey of all participants, and site visits to 13 of the initial 34 programs. Twenty-eight of these programs were characterized as development programs; the remaining six as research programs. Findings confirm the value of well-designed professional development experiences.

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[1] This summary of evaluation findings is an update of the document, *Best practice in action: Final report of the multi-agency study of teacher enhancement programs*, Frechtling (1997) published by Westat, Rockville, MD.

> Not only were they seen by participants to be personally and professionally valuable, but also the data show that a teacher's participation has important effects on what happens in the classroom. Second, in the short term, programs that are tied directly to what is desired in the classroom have the most immediate payoff. Third, the school or district context, and the support provided for the application of learning make a big difference in the extent to which changes actually occur. Finally, the linkage between participation in professional development activities and the promotion of teacher leadership and dissemination of benefits is weak. Without explicit supports and direction for such undertakings, they are not likely to occur in any consistent or meaningful way.

The basic goal of professional development programs is to broaden and deepen the disciplinary and pedagogical knowledge of teachers. Attention to issues of professional development has increased since the beginning of this decade, when the President and 50 state Governors included improved professional development for teachers as one of eight national education goals:

> *By the year 2000, the Nation's teaching force will have access to programs for the continued improvement of their professional skills and the opportunity to acquire the knowledge and skills needed to instruct and prepare all American students for the next century.* (National Education Goals Panel, 1993)

Professional development programs in science and mathematics education have been the subject of widespread interest in recent years. This emphasis reflects, in part, the heightened importance of teacher education to systemic educational reform. Essentially, systemic reform calls for coordinated changes in all parts of the educational system to ensure that new and higher standards of achievement in science and mathematics are met by *all* students, regardless of gender or ethnic and linguistic background. Educators agree that the fundamental changes required to produce both academic excellence and equity rest largely on the continued growth and professional development of the Nation's teaching force. Reflecting that understanding, each year thousands of teachers take advantage of the opportunities for professional growth offered through a variety of means ranging from limited teacher workshops during the school year to summer institutes and multi-year programs of study.

These activities, generally known as "professional development programs," share one or more of the following goals:

- Broadening teacher knowledge and skills;
- Helping teachers apply new knowledge and skills in the classroom;
- Increasing teachers' awareness of hands-on and laboratory materials and developing strategies for use in the classroom;
- Increasing teachers' understanding of careers in mathematics and science and the skills needed for them; and
- Fostering teacher leadership.

Within this general framework, two types of more comprehensive programs are generally distinguished.

> *Development programs* are multidisciplinary offerings typically held in classroom settings at local colleges, regional education service centers, county or central/district offices of education, or laboratories. Normally these programs run from 2 to 4 weeks and include presentations, demonstrations, lectures, hands-on activities, cooperative group work, field work, and time for discussion, planning, and reflection. These programs usually focus on encouraging a "hands-on/minds-on" instructional approach and have a primary goal of changing curriculum, instruction, and assessment.
>
> *Research programs* are similar in many respects, but they tend to be more intense and focused on immersing teachers in the scientific process by carrying out research projects in a university or federal laboratory setting under the guidance of working scientists. As initially developed, these programs were intended to engender a deep understanding of the research process in teachers and increase their knowledge about emergent content areas. Transfer to teaching and the classroom was seen as one byproduct of this increased understanding.

Both types of professional development programs may be a single year or multi-year experience and generally include followup sessions during the school year. Both also may provide additional materials or resources for participants to use in their classrooms.

Despite their importance to educational reform, professional development programs, including these more indepth, comprehensive experiences, have until quite recently been the subject of relatively little comprehensive evaluation. Further, most of the studies reported in the literature have relied solely on teachers' self-reports. The majority of these evaluations looked at participant satisfaction with the programs and examined reported impacts on teacher renewal and enthusiasm for teaching. A much smaller number also looked at application of knowledge to the classroom. These studies typically concluded that most participants feel satisfied with the programs they attend, enjoy the opportunity to network with their peers, use what they have learned once back in their classrooms, share what they have learned with others, and believe that their new teaching behaviors have beneficial effects on their students (Frechtling, Sharp, Carey, & Vaden-Kiernan, 1995).

While such reports are encouraging, direct evidence of changes in classroom practice and resulting improvements in student performance have been sorely lacking. Understanding this situation and recognizing the problems it posed, the Dissemination and Evaluation Working Group (DEWG)—a government body operating under the National Science and Technology Council—coordinated an effort by federal agencies that support professional development projects to undertake an extensive evaluation of their efforts.[2] As a result, a multifaceted study was initiated in 1994. This chapter presents the results of that study.

Study Overview

Working through DEWG, six agencies initiated a study of professional development programs: the Departments of Energy (DOE), Education (ED), and Health and Human Services (HHS), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the Smithsonian Institution. The work was coordinated by NSF and carried out by three independent research firms—Westat, SRI International, and the National Center for Improving Science Education. In the long term, the evaluation and other efforts of the DEWG were designed to meet two basic goals:

- Identifying those government-supported professional development programs in science, mathematics, and technology that are most effectively implementing and encouraging "best practice," and

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[2] The DEWG was an interagency group whose mission was to enhance and expand the evaluation and dissemination of mathematics and science programs.

- Assessing the extent to which these programs are contributing to the national effort to improve science education in the schools.

More immediately, this evaluation was designed to document the teaching practices promoted in the selected professional development programs believed to represent best practice in science education at the time of study initiation. The study examined the impact of these programs on teachers and their teaching, assessed the extent to which dissemination took place, and determined participant satisfaction with the programs and their outcomes. In addition, the study tried to identify the contextual factors that affect a teacher's ability to apply new learning and use new approaches in the classroom setting.

Based on an extensive review of the professional development literature available in 1994, best practice was defined in terms of four elements:

- An instructional approach that emphasizes hands-on/minds-on activities;
- A standards-based approach that aligns curriculum, instruction, and assessment with local, state, or national standards or frameworks;[3]
- Development activities that extend over time, including followup when participants return to their schools; and
- Direct involvement of participants in the scientific process.

Using these and other selection criteria, program officers from each of the six agencies nominated professional development programs that they considered successful in delivering professional development in science teaching. Additional considerations governing selection were 1) stability[4]; 2) inclusion of teachers who themselves were from populations traditionally underrepresented in science or who work with significant numbers of students from those underrepresented groups; and 3) inclusion of programs that were carried out within a systemic reform context.

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[3] See National Council of Teachers of Mathematics (NCTM), National Research Council (NRC), and Project 2061's *Benchmarks* (Listed in References at the end of this chapter) for descriptions of standards-based instruction and professional development.

[4] It is recommended that programs nominated be in at least their second or third year of operation to avoid first-year, startup problems.

Thirty-four programs identified through this process were selected for the evaluation. Twenty-eight of the programs were characterized as development programs and the remaining six as research programs. The evaluation of these combined professional development efforts was carried out in two phases, summarized in Exhibit 1. During Phase I (summer 1994), evaluators made site visits to the 34 professional development programs while they were in progress, documenting program events and practices, reviewing program materials, and interviewing participants and other key players. The purpose of these visits was to document the extent to which programs exhibit the characteristics of best practice.

During Phase II, the evaluators looked at the impacts of participation on teachers when they returned to their classrooms. Two complementary techniques were used: a survey of both 1993 and 1994 program participants from each of the 34 programs; and more indepth analyses (called "case stories") of participants from 13 programs; these programs were selected because of variation in their design and implementation. The survey was used to get a broad picture of teachers' perceptions of the programs and their impacts. The case stories were designed to gather data that would corroborate (or refute) the findings from the surveys, as well as to provide a more indepth picture of program results in a limited number of cases. Detailed reports of the separate components of this study have been presented in a series of reports issued between November 1995 and March 1997.[5]

The Impacts of Professional Development Programs

The multi-agency study provided confirmation of a number of previous findings regarding professional development programs. First, the participants in these programs are not entirely representative of the U.S. science teaching force. While they resemble the overall teaching force in terms of age, number of years teaching, gender, racial/ethnic distribution, and major field of study, as a group they have a higher preponderance of advanced degrees and are more likely to have participated previously in extended professional development

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[5] Phase I methodology and findings is presented in Ruskus and Luczak (1995). The findings from the site visits are presented in Westat, Natonal Center for Improving Science Education, and SRI International (1996). The findings from the survey are presented in Carey and Frechtling (1997). The present report summarizes some of these study findings.

Exhibit 1. Study design

Best practices evaluation of professional development (TE) programs		
Phase I. Program Documentation and Description *(Summer 1994)*	Phase II. Participant Followup *(1994-95 School Year)*	
Site visits *34 TE programs exemplifying best practice* • Modeling of best teaching practices • Immersion in "doing science" • Standards-based professional development • Followup activities	Mail (census) survey *All 1993 and 1994 participants from 34 Phase I programs* • Changes in teaching behaviors • Participant satisfaction • Feelings of renewal • Leadership roles/knowledge dissemination • District/school effects on other measures	Site visits *1-2 teachers from 13 of the Phase I programs* • Evidence of best practices transferred from the program • Objective validation of self-report data from survey

programs than the national population (Tables 1, 2, and 3). Thus, the findings reported here, as in other programs that primarily serve volunteer populations, must be interpreted with that caveat in mind.

Second, the study affirmed the previous reports that from a personal point of view, participation in summer institutes and followup activities is seen as very valuable and energizing. The following comments from participants in teacher development programs (Carey & Frechtling, 1997) were typical:

Table 1. Percent distributions of teacher development participants, by teacher characteristics and by grade level (n = 1,481)

		Grade Level		
Teacher Characteristics	All Participants	Elementary 1-6	Middle 7-8	Secondary 9-12
Whole sample	100%	32%	31%	37%
Gender				
Female	65	85	27	41
Male	35	15	73	59
Minority status				
White	83	84	78	87
All other races	17	16	22	13
Advanced degree				
Yes	59	52	60	65
No	41	48	40	35
Major field of study				
Education	59	87	70	26
Science or math	33	6	19	69
Other	7	7	11	5
Number of years teaching				
5 or less	25	23	16	15
6 to 19	52	54	53	52
20 or more	22	22	31	33
Administrative position held in school				
Department chair	18	21	14	20
Curriculum coordinator	10	11	13	6
Other administrator	17	11	15	23
None	55	56	58	51
Attended other science teacher enhancement programs of 40 hours or more in the past 3 years				
Yes	47	39	47	55
No	53	69	53	45

Note. Because of rounding, percents may not add to 100.

Table 2. Percent distributions of research participants, by teacher, school, and target science class characteristics (n=116)

Background characteristic	Percent of teachers
Teacher characteristics	
Gender	
Female	31
Male	69
Minority status	
White	87
All other races	13
Advanced degree	
Yes	82
No	18
Major field of study	
Education	16
Science or math	80
Other	3
Administrative position held in school	
Yes	45
No	55
Attended other science teacher enhancement programs	
Yes	55
No	45
School characteristics	
Metropolitan status	
Central city	30
Urban fringe	32
Town	18
Rural	20
Percent minority enrollment	
Less than 10	52
11 to 50	28
More than 50	20
School reform in science education	
Yes	58
No	42
Target class characteristics	
Instructional level	
Elementary (1-6)	0
Middle (7-8)	15
Secondary (9-12)	85
Ability level of students	
Low ability	2
Average ability	23
High ability	34
Mixed ability	41

Note. Because of rounding, percents may not add to 100.

Table 3. Population statistics for U.S. science teachers

Teacher characteristic	Grade Level		
	Elementary (1-6)	**Middle** (7-8)	**Secondary** (9-12)
Gender			
Female	91%	69%	34%
Male	9	31	66
Minority status			
White	88	89	95
All other races	12	12	5
Master's degree			
Yes	34	42	57
No	66	58	43
Major field of study			
Science	2	17	63
Science education	0	2	6
Other education	86	63	22
Other fields	12	18	10
Number of years teaching			
5 or less	23	23	21
6-19	58	53	44
20 or more	19	25	35
Hours of professional development in last 3 years*			
None	43	23	21
Less than 16	51	53	55
16-35	4	16	13
More than 35	3	9	11

*Weiss and colleagues report professional development by hours. Also, elementary grades for these data are 1-4, and middle grades are 5-8.

Note: Because of rounding, percents may not add to 100.

Source: J. Weiss, M. Matti, and P. Smith, Report of the 1993 National Survey of Science and Mathematics Education, Chapel Hill, NC: Horizon Research, Inc., 1994.

> *Rejuvenation of the desire to teach great science! Ideas, stories, resources and support from everyone resulted in a feeling of power and joy in doing science in the classroom. Confidence in knowing what I wanted to do was right and it would work.*
>
> *I returned to my school so motivated about teaching that other teachers were aware of my "glow." It was the greatest mood lifter I have had in a very long time.*

In addition, the study documented some other outcomes that help us better understand the more far-reaching benefits that well designed programs can provide. These findings are explored in more detail below.

Effects on Classroom Practices

The central question driving the multi-agency study was whether or not evidence can be found that the benefits of professional development programs extend to the classroom and the delivery of instruction. Based on the combined results of the case stories and the surveys, it is our conclusion that the answer is a cautious "yes."

We found considerable evidence that teachers were applying what they had learned about standards-based instruction in science to their classrooms. And, although not all teachers achieved the same level of competency, all groups showed progress and provided evidence of improved teaching. Gains were found for participants in both teacher development and teacher researcher programs.

Instructional impacts were explored through a variety of means. In the case stories, a fundamental question addressed in the classroom observations and interviews was whether or not teachers were using hands-on, inquiry-based methods and whether classroom activities reflected the content, instrumentation, or techniques introduced in the summer programs. The surveys queried teachers about their teaching practices and the frequency with which students engaged in various kinds of activities. Teachers were asked to report on the use of selected teaching strategies both prior to and after their summer experiences.

Taken together, the findings show considerable use of many of the elements of best practice and suggest that teachers' professional development experiences both reinforced and introduced standards-based practices that ultimately were translated into classroom instruction. For example, a participant in one of the teacher development programs who was observed using hands-on techniques that were partially inquiry-based stated:

> *I have always used hands-on experiences with my students, even before [this program dealing with museum experience].*[6] *The program helped to give me more creative ideas and experiences to use in my science classes....I guess Museum in the Field did not change my teaching style, but enhanced it.*[7]

At another site the observer drew the following conclusions about Susan, a participant in one of the teacher development institutes, focused on space science:

> *At Susan's school, the infusion of space science from K-6 is a direct outcome of the materials that the program provides. The entire elementary science program at this school is built around the ideas of inquiry, exploration, and hands-on experience of the phenomena under study...Susan clearly demonstrated hands-on inquiry-based teaching throughout the 90-minute lesson.*

Finally, corroboration of impact was frequently found in interviews with supervisors and colleagues. Again, in another case story, the following was reported:

> *The principal believes that..."he [the participating teacher] would have left education without this experience. I've seen [teaching] changes this year. He has more confidence that what he's presenting is relevant to students. He stresses relevance in whatever he does. He's more hands-on than any other science teacher, and this is how it should be..."*

This is not to say that all programs prepared teachers to successfully translate what they learned to classroom activities. For example, our research program, rated very valuable in terms of participants' own acquisition of new skills and knowledge, failed the translation test.

> *Steve indicated that he could not use much of the content from the program in his classes...the subject matter is far too esoteric for any high school classroom application.*

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[6] In referring to programs, we use the pseudonyms assigned in Ruskus and Luczak, 1995.

[7] Programmatic examples are taken from Westat, National Center for Improving Science Education, and SRI International, 1996.

Survey data (Carey & Frechtling, 1997) support the conclusion that program participation impacts classroom instruction. At the same time, however, the data indicate that not all aspects of standards-based instruction were realized with equal strength. For example, while 59 percent of the participants in teacher development programs indicated that they were using new hands-on research projects and 50 percent reported using new explanations or examples in their teaching, only 37 percent indicated that they had made changes in their use of alternative assessments.

Figure 1 shows the reported changes in teacher practices for six specially selected pairs of behavior among teachers attending teacher development programs. One member of each pair represents more traditional teaching practices; while the second represents more current views about best practices. As the exhibit shows, while change in the desired direction occurred for each of the pairs of practices, gains were not uniform, and levels of implementation differed substantially after program participation

An interesting contrast can be found at pairs *a* and *c*. Although the reported prevalence of the two practice choices is roughly the same in *a* and *c* prior to the program participation, the amount of change toward use of best practice is substantially different. Pair *a* contrasted use of cooperative learning with student independent work. There, the use of cooperative learning increased from 33 percent of the participants reporting substantial use to 74 percent selecting this response. The corresponding decrease in student independent work went from 37 percent to 6 percent reporting frequent usage. Pair *c* contrasted indepth study of selected topics with comprehensive coverage of topics at the expense of detail. Indepth coverage increased from 27 percent prior to participation to 48 percent after participation. The corresponding figures for comprehensive coverage were 36 percent to 22 percent. It is easy to see that while both of these changes would be considered positive, the reported adoption of indepth study changes far less and reaches a much lower end level than that of cooperative learning.[8]

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[8] This relatively more limited attention to indepth study of topics is confirmed by data from studies such as the Third International Mathematics and Science Study, which indicates that U.S. teachers adopt indepth coverage far less than their international counterparts.

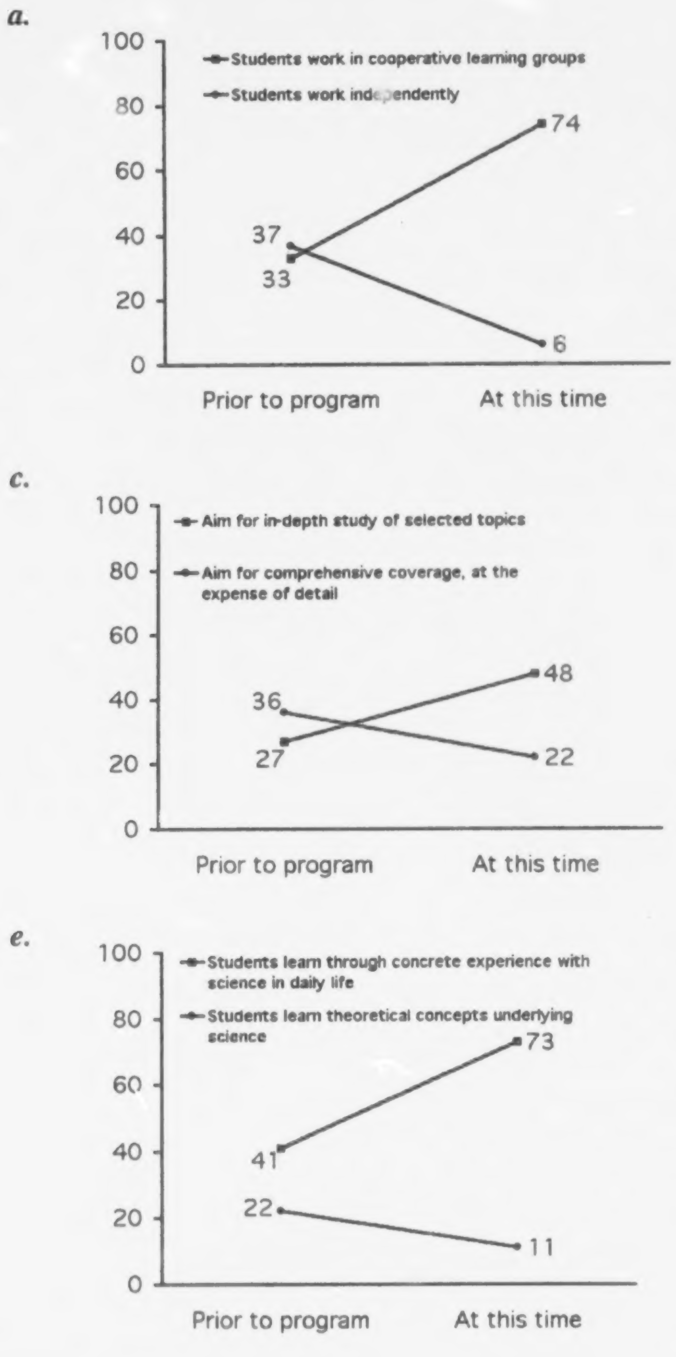

Figure 1.
Percentage of participants reporting change in use of various teaching techniques after participation in teacher development programs*

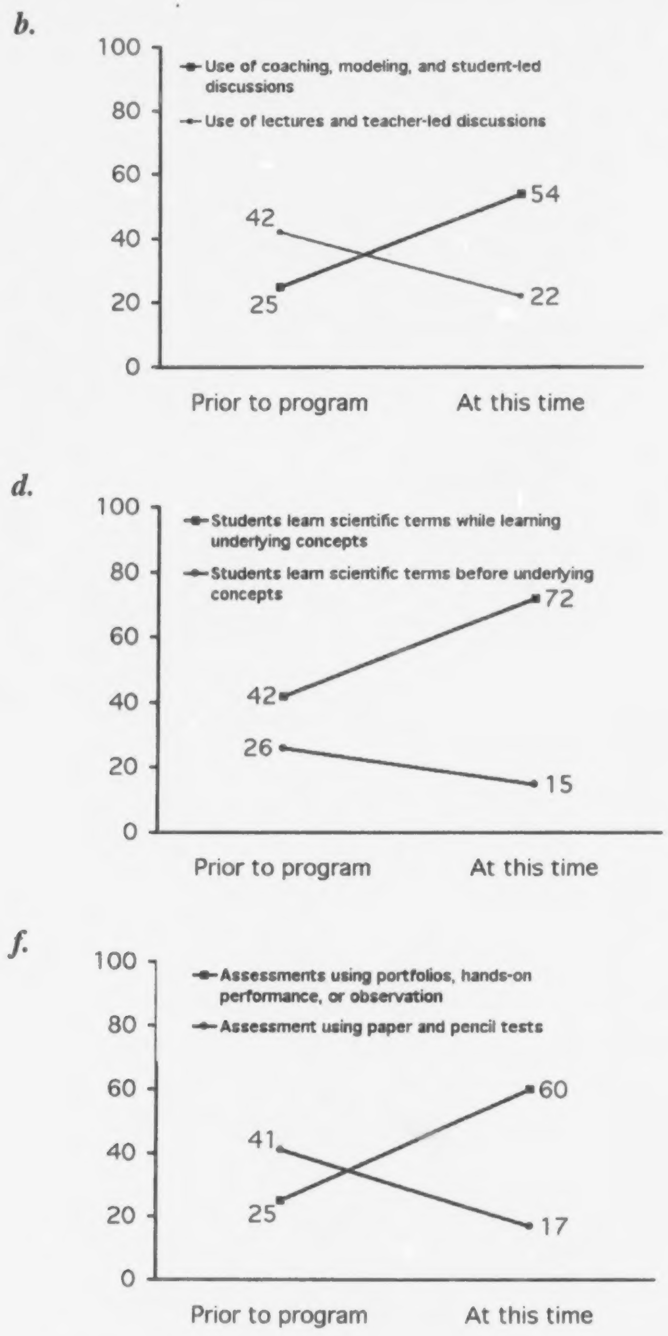

*Exhibit contrasts those reporting high usage—4 or 5 on a 5-point scale—with those reporting low usage—1 or 2 on a 5-point scale.

Differences were also found when the data for the teacher researcher programs were examined (Figure 2). Again, while change was in the right direction for all pairs of practices examined, changes were uneven and differed sharply in some cases from the teacher development programs.

The study also found some important differences in extent of classroom application when teacher characteristics were considered.[9] Characteristics associated with fuller translation to the classroom included

- initial level of use of standards-based techniques—those who already used standards-based instruction before program participation were more likely to show more use of these practices after program participation;
- school level—teachers who were at the elementary/middle level were more likely to report using instruction reflective of best practices than were high school teachers; and
- autonomy—teachers who had a greater sense of control over their environments reported greater changes than those who felt they had less control.

However, one of the most important findings was that there was no difference in the benefits received by teachers from different racial/ethnic groups or teachers who taught different types of students. Although the data from the case stories suggest that certain environments pose greater challenges than others, and in absolute terms standards-based instruction was found to be less prevalent in the central city and urban fringe schools than in the suburbs, the benefits of professional development were in evidence across the board. Thus, it appears to be important to encourage teachers working with urban populations to participate as fully as possible in high-quality professional development programs. Clearly, policymakers would be well advised to consider ways of providing incentives for such teachers, and for the programs that serve them.

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[9] These analyses of differential effectiveness for different types of teachers were only carried out for those participating in the teacher development programs. Because of the relatively smaller sample of participants in the researcher programs, these more fine-grained analyses could not be carried out. This issue is considered further in the next section on characteristics of the most effective programs.

Effects of Program Characteristics

A second question of central interest was whether or not we could identify programs that appeared to be most effective in promoting change in classroom practices and, if we could, what the characteristics of the more effective programs might be. The results of the study indicated that teacher development programs that provided experience with the "model science classroom" had the most immediate impact on classroom practice. For the teachers in the development programs, experiences related to research and the research process showed relatively less classroom impact.

What does it mean to provide experience with the model science classroom? Although there is no one way to do this, the general notion is that these programs provided direct experience in using and developing the kinds of instructional practices that it is hoped the teachers will eventually incorporate into their day-to-day teaching. This contrasts with programs that placed greater emphasis on the scientific experience, on doing, learning about, or observing scientific research. Characteristics of these more effective programs include

- participating in hands-on activities for use in the classroom,
- planning how information could be used in the classroom,
- developing curriculum units,
- engaging in challenging problem solving,
- collaborating with scientists or other staff, and
- interacting with program participants.

While the results for the teacher development programs were relatively clear, the picture for the teacher researcher programs was not. Because of sample size limitations, we do not know from this study what the relative impacts of well-implemented teacher researcher programs might be compared to other approaches, and the potential benefits of the research experience require further examination.

We did find, however, that the two types of professional development programs attracted different types of teachers. Participant differences can be classified into three general categories: personal, school, and classroom characteristics.

1. Personal characteristics: Relative to participants in teacher development programs, those in research programs

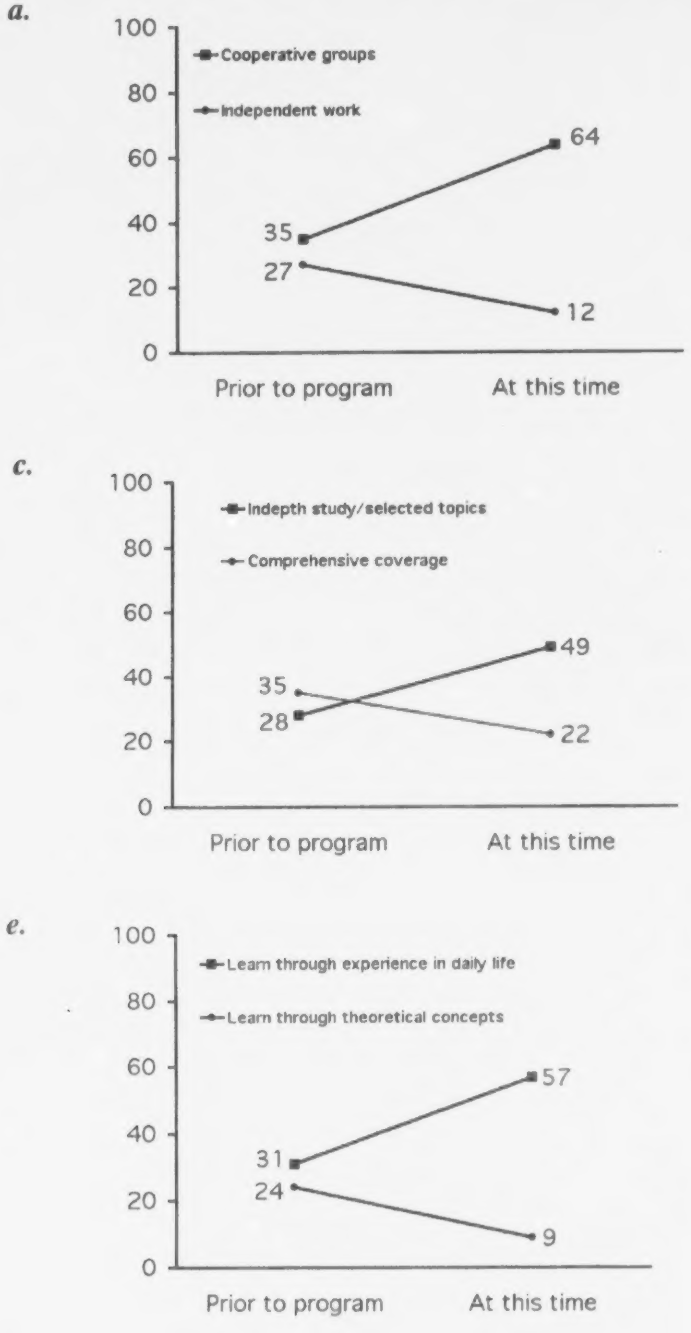

Figure 2.
Percentage of participants reporting change in use of various teaching techniques after participating in research programs*

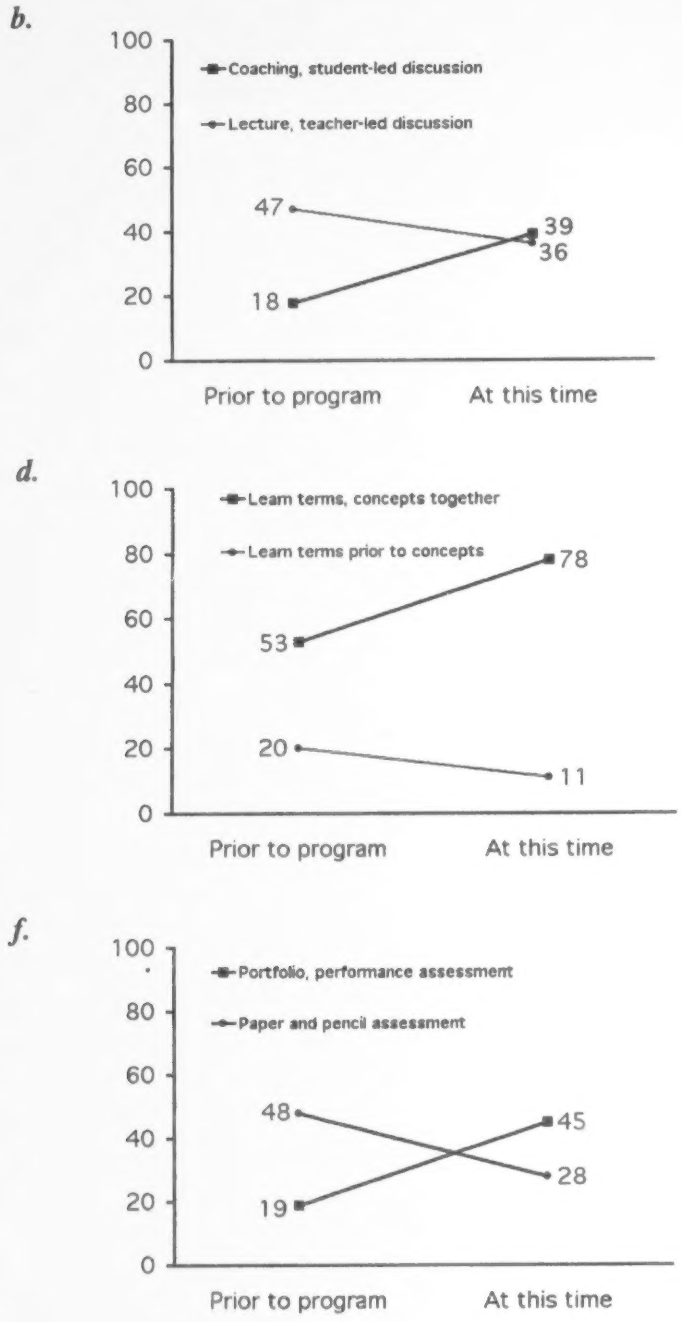

*Exhibit contrasts those reporting high usage—4 or 5 on a 5-point scale—with those reporting low usage—1 or 2 on a 5-point scale.

- were more likely to be male (69 versus 32 percent), and
- more often had degrees above a bachelor's (82 versus 57 percent).

2. School characteristics: Participants in research programs taught in schools that were more often
    - secondary (85 versus 32), and
    - private (14 versus 5 percent).
3. Classroom characteristics: Participants in research programs taught science classes that were more likely to
    - meet for 5 or more hours per week (65 versus 37 percent), and
    - be composed of higher ability students (34 versus 16 percent).

While we cannot say what would have happened to the teacher researcher participants had they attended teacher development institutes (and statements about relative gain cannot be derived from the study), it is clear from Figure 2 that overall, the research participants gained skills and knowledge that were associated with changes in classroom practice. This suggests that changes in practice can be attained in a variety of ways. The model classroom may be a very effective, but not the only effective, way to promote changes in classroom instruction. More attention needs to be given to developing an understanding of the benefits of different strategies for different teachers or for teachers at different points in their careers.

Teacher Leadership and Dissemination of Findings

A commonly held belief is that teachers who participate in summer institutes and other extended professional development efforts will not only change their own classroom practices, but they also will work with other teachers in their schools or districts to bring about more widespread change. The belief, or hope, is that by investing resources in the training of one or two teachers, many more teachers will be reached.

Findings from the study suggest, however, that this belief is not readily substantiated. Granted, teacher leadership was not an explicit goal for the majority of programs, and strategies for dissemination were covered lightly, if at all. However, many of the programs cited dissemination as a desired benefit, and dissemination of new practices is frequently mentioned as a general goal of professional development activities.

Both the case stories and survey data strongly indicate that formal dissemination of knowledge and practice was a relatively rare event. Figures 3 and 4 present responses from the teacher development and teacher researcher participants regarding their dissemination activities. These data show that in general, little direct dissemination of knowledge and skills resulted from program exposure.

However, in our program where leadership was a major focus, a somewhat more positive picture emerged. The case story found:

> *All the teachers interviewed, with the exception of one who worked primarily alone, had shared what they had learned in the program with others. They had done so through holding demonstrations in their own classrooms for other teachers to observe, conducting workshops for their colleagues at different times, guiding teachers through FOSS kits, and working closely with the program's mathematics representatives or science representatives at different grade levels. Most of their activities were confined to their own buildings unless they were teacher leaders who had responsibilities at other schools. Their formal contacts with teacher-participants in schools other than their own were limited primarily to their regular institute sessions. The amount of sharing varies by building.*

This relative lack of leadership in dissemination among the majority of participants is especially noteworthy as a number of other indicators suggest that the teachers who participate in summer institutes are among the more outgoing and may already have held leadership positions in their schools or districts. While one reason may be the lack of formal emphasis on dissemination in most of the programs, another is probably the lack of time and/or support when the teachers return to their schools. This latter issue, and the overall role of the school or district context, is discussed in more detail below.

The Importance of Supports at the District and School Levels

Many people strongly believe that the most effective strategies for professional development tie the development directly to the context of a particular district or school and rely on the teachers themselves for

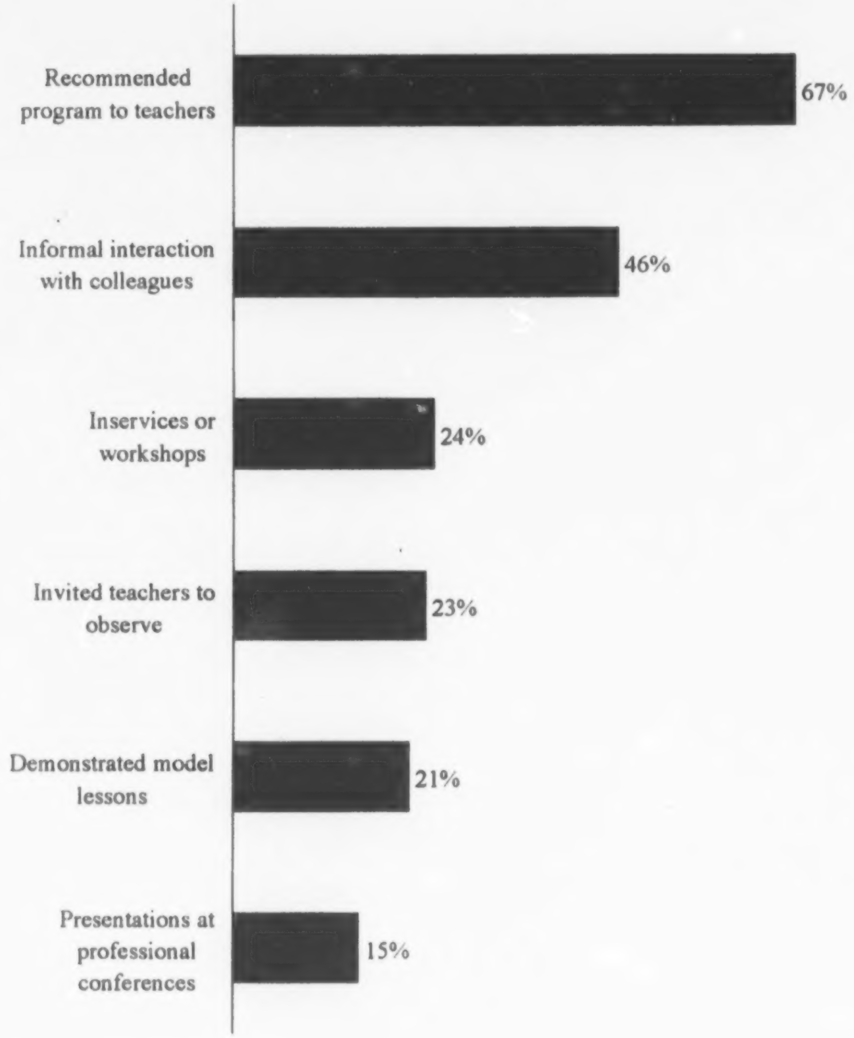

Figure 3
Percent of participants in teacher development programs saying they have shared and disseminated knowledge gained in the program to a great extent

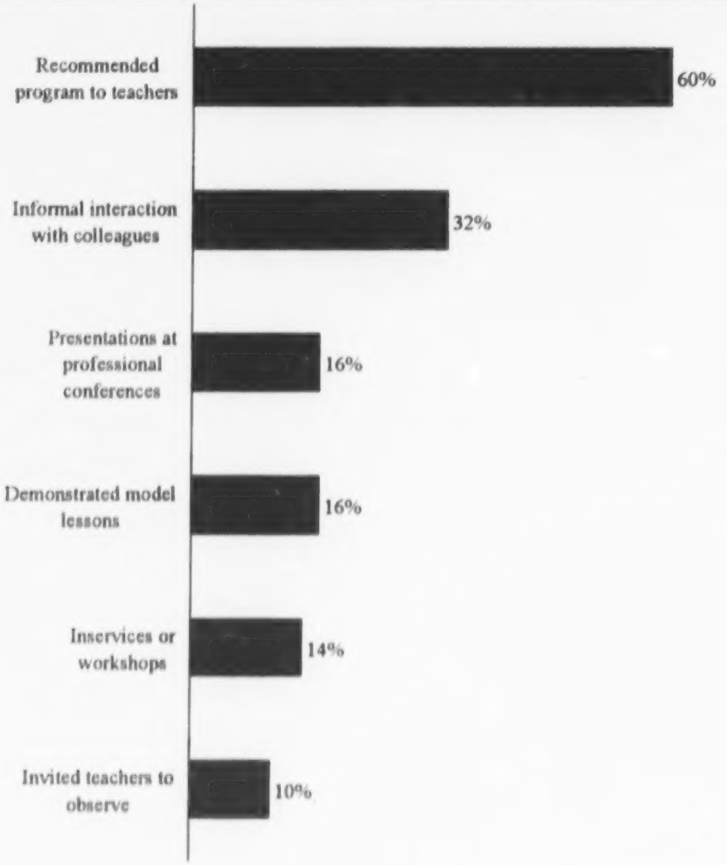

Figure 4
Percent of research participants saying that they have shared and disseminated knowledge gained in the program to a great extent

planning the program and designing (or in some cases providing) its content (Lieberman, 1995; Darling-Hammond, 1995). These researchers advocate models that tie professional development to a particular school and are explicitly linked to reform activities that the school is undertaking.

At the time that the multi-agency study was initiated, the emphasis on the individual school-based model was not as strong as it is today. Rather, the emphasis was on ensuring that professional development efforts were designed as sustained and extended experiences that would be supported by school or district personnel.[10] Ties might be explicit in terms of integration with systemic reform efforts or implied through loosely structured agreements with school authorities. For example, many programs required that a teacher's principal sign a letter agreeing to have the teacher participate as a condition of enrollment. Underlying this requirement was the belief (stated or unstated) that this signature served as a proxy for future support to the teacher in using and sharing new skills after program participation.

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[10] This is not to say that teacher input was unimportant. However, this input was sought more frequently in terms of evaluation and feedback rather than planning and direction.

The present study affirms the importance of support at the school or district level and was critical in assuring application of the lessons of the professional development experience. The impact of the professional development experience—translation to classroom instruction, leadership, dissemination, etc.—was strongly affected by the district or school context already in place. As stated earlier, more translation to the classroom was found where teachers felt they had more control over their schools and classrooms. The case stories also suggest that teachers with a supportive administrator are able to make the most changes. Some contrasting examples are found in one of the case stories.

> *Bob considers his principal to be supportive. He said that the principal seems to have an interest in science. If it's within reason, the principal will give Bob release time to attend a function and will spend money for the classroom....*
>
> *Two participants indicated that they receive much psychological support but little financial support for computers, other equipment and supplies....Another teacher receives no support from his department chair. He was "called on the carpet" by the principal for not having his students use the textbook.*

Another important factor affecting classroom implementation is the availability of materials and equipment. It was clear that many of the new skills and techniques learned at the institutes could not be implemented, or were far more difficult to implement in situations where needed materials and equipment were not available. For example, a case story that focused on the impacts of an institute aimed at enhancing teachers' ability to use computers found the following:

> *The greatest barriers that teachers perceive in their classroom implementation of [a program focusing on computer usage] are ... no money to buy updated computers; lack of access to*

> *computers in the classroom; and lack of available software relevant to the content areas being taught.*

Recognizing this factor, some programs have built materials provision into their programs. In some cases, low-cost, easy-to-access materials are provided to teachers in the "make-and-take" mode. In other cases, traveling vans bring high-end equipment directly to the schools to use for a limited period of time.

However, material and equipment supports are not the only, or even the most important, factor in determining whether changes in practice take place. A more important facilitator is the general reform climate in the school or district and the "readiness for change." The survey data showed that in addition to teachers' previous practices, level of school taught, and sense of autonomy, a major facilitator of transfer was teaching in a school in which there was already some kind of reform being implemented.

These findings, taken together, reinforce the importance of professional development programs having more than a superficial tie to the school and highlight the need for a strong commitment of support if the goal of improved classroom learning is to be widely attained. To a large extent, the findings also lend credence to the importance of school-based programs and suggest that such programs may provide the most immediate effect on changing practices. At its best, the school-based model brings with it a number of characteristics shown by this study to be needed for change to occur—a readiness for change, a supportive administrative structure, a cadre of peers who can support each other, and time for trying out new approaches and introducing new content—all critical supports for change.

The results also indicate that the school- or district-based model is not the only one that can be effective. Many participants in professional development programs with a regional and even national target population were able to make significant changes in their classroom practice. What seems to be most important is making sure that certain predisposing conditions are established in the school or district—a significant challenge in far too many instances.

Conclusions

Taken together, the results from this multi-agency study provide some valuable insights into the effects of participating in professional development programs. First, the findings confirm the value of well-designed professional development experiences for those who attend. Not only were they seen by participants to be personally and professionally valuable, but the data show that a teacher's participation has important effects on what happens in his/her classroom. Although we cannot say that these experiences result in increased student achievement, we do know that they contribute to establishing the conditions under which improved achievement is likely to occur. Programs that provide teachers increased knowledge about, and practice in, delivering standards-based science instruction result in students being provided pedagogy and broader exposure to relevant and important science content.

Even among this self-selected group of attendees, however, there were some important differences in outcomes. Some practices associated with standards-based instruction were evidenced far less frequently than others. For example, it appears difficult for teachers to change from limited coverage of a wide range of topics to more indepth consideration of a few topics. Some teachers also are resistant to giving up a teacher-centered approach. And, while hands-on, instruction was the most widely observed practice, there were still indications that more progress could be made in assuring that *hands-on* really means *minds-on*, rather than a more superficial adoption of active engagement.

Second, programs that model the ideal science classroom, including participating in hands-on activities for use in the classroom, planning how information could be used in the classroom, developing curriculum units, engaging in challenging problem solving, and collaborating with scientists or other staff, are the most effective in facilitating this transfer. While we cannot be certain that this approach is preferable in the long run, in the short term programs tied directly to what is desired in the classroom have the most immediate payoff.

Third, the school or district context, and the support provided for the application of learning, make a big difference in the extent to which changes actually occur. While it is certainly possible for the lone teacher, unsupported by administrators and colleagues, to make a difference, the chances of this occurring are far less than in a supportive environment. This finding raises some possible dilemmas. Specifically, should teachers be denied access to professional development if the school or district commitment for support is not adequate? And, what are the characteristics of an adequate commitment? Clearly, a signature on a letter of application is not. Materials and equipment support, release time to attend followup sessions, and work with other teachers are more desirable. Having teams of teachers participate is also a potentially effective strategy. These, plus an explicit tie-in to an ongoing plan for reform, are probably the best. The very difficult question is how far program managers should go in defining and requiring commitment from home schools and districts.

Fourth, the question of moving the high school teacher toward greater reform remains a significant challenge. The good news is that participants who teach at the high school level do make changes; the bad news is that these changes are significantly smaller in magnitude. This is not the first study to note that it is more difficult to change the behavior of high school teachers than teachers in the earlier grades (Cuban & Tyack, 1995). However, how to change this phenomenon remains an open question, and a closer look at the relative efficacy of programs that target this population seems warranted.

Finally, those who are interested in using professional development programs as a way to promote teacher leadership and dissemination of program benefits need to recognize that the link between program participation and sharing of information is not necessarily given or naturally evolving. A variety of factors affect whether or not a teacher is able to share what has been learned with others. While this is no doubt related to the environment of the school, there are a number of ways in which the professional development program can increase the likelihood that such sharing occurs. First, teachers must be made aware that it is an expectation of their program participation. Second, administrators in the schools where participants teach need to make a commitment that they will not only encourage their leadership in information dissemination, but will also provide time and support for it to occur. And, third, professional development programs need to include activities specially designed to build the capacity of teachers to become leaders in the educational change process, helping them to both identify strategies for playing more visible roles and giving the skills needed to promote the acquisition of the new understandings among their peers and colleagues.

References

Carey, N., & Frechtling, J. (1997). *Best practice in action: Followup survey on professional development programs*. Rockville, MD: Westat, Inc.

Cuban, L., & Tyack, D. (1995). *Tinkering toward utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.

Darling-Hammond, L. (1995). Practices that support teacher development. *Phi Delta Kappan*, April: 591-596.

Frechtling, J., Sharp, L., Carey, N., & Vaden-Kiernan, N. (1995). *Professional development programs: A perspective on the last four decades*. Washington, DC: National Science Foundation, Division of Research, Evaluation and Communication.

Lieberman, A. (1995). Policies that support professional development in an era of educational reform. *Phi Delta Kappan*, April: 597-604.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics and standards for teaching mathematics*. Reston, VA: NCTM.

National Education Goals Panel. (1995). *Data volume for the National Education Goals Report 1995*. Washington, DC: Author.

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

Project 2061, American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Ruskus, J., & Luczak, J. (1995). *Best practice in action: A descriptive study of exemplary professional development institutes in science and technology*. Arlington, VA: SRI International.

Westat, National Center for Improving Science Education, and SRI International. (1996). *Best practice in action: Case stories*. Rockville, MD: Westat, Inc.

4

Effective Professional Development for Teacher Leaders: Lessons Learned from K-6 Mathematics Teacher Enhancement Program

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The National Science Foundation (NSF) has supported a wide variety of teacher enhancement projects in order to identify and explore strategies that are effective in bringing genuine, long-term teacher change, and, ultimately, long-term systemic change in schools. In November 1994, with funding provided from NSF, a small, informal conference was held that focused on teacher enhancement in elementary mathematics education with the goal being to organize, summarize, and discuss what is known about factors for effective teacher enhancement. A number of common principles emerged that may be used to guide development of teacher enhancement programs in K-6 mathematics education. This article summarizes these principles, with special attention given to professional development for teacher leaders.

> *Mathematics teachers develop professionally in the same ways all other teachers do but with a specific focus of applying professional knowledge within a meaningful and relevant mathematical context for the improvement of the mathematical understanding of children and youth.* (Castle & Aichele, 1994, p. 3)

For a number of years, there has been general agreement that K–12 mathematics teaching in the United States is in critical need of major reform. In responding to this identified need, the National Science Foundation (NSF) has supported a wide variety of teacher enhancement projects in order to identify and explore strategies that are effective in bringing genuine, long-term teacher change, and, ultimately, long-term systemic change in schools. These "pilot" or "experimental" programs have permitted NSF and the principal investigators to explore a variety of strategies for working with teachers to promote changes in the ways they teach and facilitate student learning of mathematics.

In November 1994, with funding provided from NSF[1], a small, informal conference was held that focused on teacher enhancement in elementary mathematics education. Conference attendees included recognized experts in professional development and teacher change for K–6 teacher enhancement, primarily in mathematics. They were convened in order to organize, summarize, and discuss what is known about factors of effective teacher enhancement.

Based on papers prepared for the conference and discussions during the conference, a number of common principles emerged that may be used to guide development of teacher enhancement programs in K-6 mathematics education (Friel & Bright, 1997). In this article, we present a summary of the common principles; many of these principles have emerged through the practice of professional development. Clearly, each provides the potential for rich discussion and research in order to document both "how to put it into action" and to provide the evidence and rationale for why specific practices result in changes that ultimately lead to improved mathematics instruction.

These principles may be presented visually in a way that clarifies their interrelationships (Figure 1). A critical filter for any efforts for change is beliefs about the three interrelated components of mathematics teaching: knowledge of mathematics, knowledge of mathematics pedagogy, and knowledge of students' mathematical thinking. These three components frame the heart of teaching mathematics. Professional development opportunities may focus, to varying degrees, on assisting teachers in their efforts to address these components either individually or in combination. No matter what the goals of professional development[2], in the end we are asking teachers to consider the relationships among the three areas in light of their own beliefs.

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[2] Professional development in mathematics education may include: summer workshops, scheduled meetings, ongoing seminars that focus on practice, follow-up professional development days for sharing, use of action research projects, classroom visits for purposes of coaching, teacher-planning time for teams to work together, or conversations among teachers between classes.

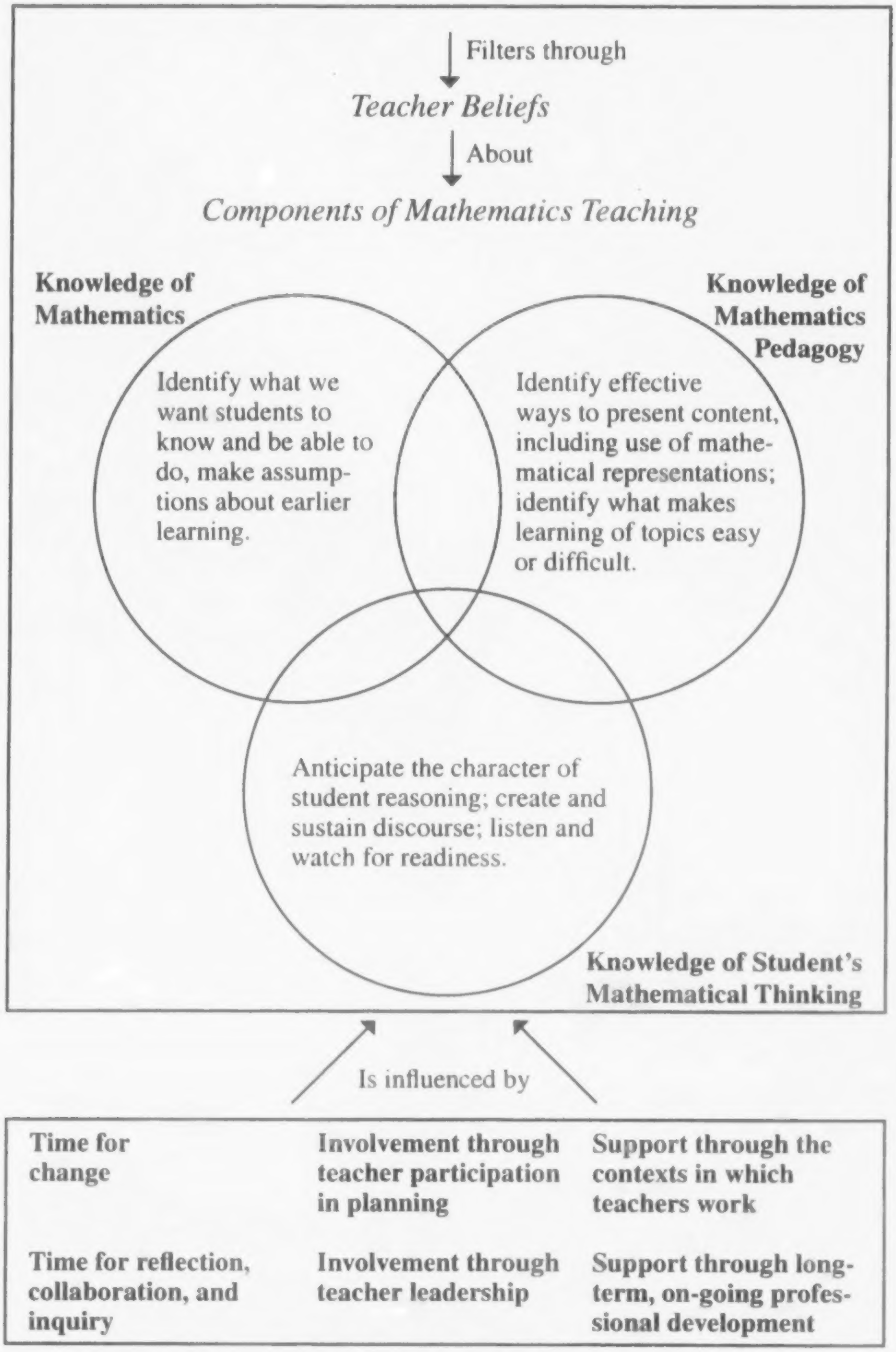
Filters through
Teacher Beliefs
About
Components of Mathematics Teaching
Knowledge of Mathematics
Identify what we want students to know and be able to do, make assumptions about earlier learning.
Knowledge of Mathematics Pedagogy
Identify effective ways to present content, including use of mathematical representations; identify what makes learning of topics easy or difficult.
Anticipate the character of student reasoning; create and sustain discourse; listen and watch for readiness.
Knowledge of Student's Mathematical Thinking
Is influenced by
Time for change
Involvement through teacher participation in planning
Support through the contexts in which teachers work
Time for reflection, collaboration, and inquiry
Involvement through teacher leadership
Support through long-term, on-going professional development

Figure 1. A Framework for Thinking about Professional Development in Mathematics Education

In addition to teacher beliefs and their interaction with the three components that frame the heart of mathematics teaching, there are a number of other factors that have an impact on effective professional development programs in mathematics education (Figure 1). These factors highlight teachers' needs for (a) time to change and to reflect, collaborate, and inquire about their practice; (b) for involvement in planning agendas for change and involvement through teacher leadership; and (c) for support gained both through the context of the school environment and through an on-going program of professional development.

Anyone who is involved in providing professional development for teachers needs a framework for their work. The framework proposed here is one example. In particular, it makes explicit issues that teacher leaders need to keep in mind as they work with their colleagues in a variety of professional development contexts.

Teacher beliefs: A critical filter

> *Most teachers and learners have well formed views on the nature of mathematics and these views have a profound influence on the way mathematics is taught and learned.* (Ernst, 1989, as cited in Laurenson, 1995, p. 3)

We know that stated beliefs may not always appear to be consistent with practice (Laurenson, 1995). Indeed, teacher beliefs about mathematics, mathematics teaching, and students' mathematical knowledge may be explicitly stated or may be implicit and not at the level of awareness on the part of the believer. Working to identify and to change teacher beliefs needs to be the first and primary work of professional development (Loucks-Horsley, 1997). However, the strategies that support changes in teachers' beliefs are not clearly defined. Recent research has indicated that when teachers experiment with their practice in teaching mathematics, they may experience changes in their beliefs (Loucks-Horsley, Hewson, Love, & Stiles, 1997).

> *It is clear that teachers' beliefs about the value of certain reformist tenets shift as a result of their tentative experimentation with practice.* (Ferrini-Mundy, 1997, p. 123)

Part of this change is motivated when teachers see evidence of student success in their classrooms during such experimentation. As teachers' conceptions of learning and mathematics change, they begin to see their classrooms through different eyes and want to interact differently with their students. Other strategies that have the potential to impact beliefs and practice include reflecting on the content of videotapes of one's own teaching of mathematics; discussing readings that focus on topics of differences in students' learning and understanding of mathematics; or analyzing cases written about the dilemmas of teaching mathematics.

Professional Development and the Components of Mathematics Teaching

Knowledge of mathematics

The importance of subject matter knowledge in learning to teach for understanding cannot be ignored. Inservice programs need to provide opportunities for teachers not only to explore their own mathematics content knowledge, but also to help teachers learn how to learn mathematics in the context of their own teaching. One way to address this is to involve teachers first in the doing of mathematics for themselves.

> *We are now confident that doing mathematics and reflecting on it makes a major contribution to a paradigm shift for many teachers in a long-term staff development program. Shifting the focus from their teaching helps some teachers pursue their own mathematical identities. Subsequently they develop more mathematical confidence... Too often in inservice meetings teachers' own mathematics is not being enhanced because the mathematics in teacher enhancement seminars is done for the children.* (Corwin, 1997, p. 188-89)

The practice of addressing mathematics for teachers as learners is not always popular with teachers; teachers involved in doing mathematics often argue that they can't afford the time (Parker, 1997). Their preference is to have new activities for their classrooms. However, with time, teachers do come to value this process and their own mathematical empowerment.

The *Professional Standards for Teaching Mathematics* (NCTM, 1991) highlight the importance of having teachers revisit school mathematics, this time from a perspective quite different than the one they held as students.

> *Too often, it is taken for granted that teachers' knowledge of the content of school mathematics is in place by the time they complete their own K–12 learning experiences. Teachers need opportunities to revisit school mathematics topics in ways that will allow them to develop deeper understandings of the subtle ideas and relationships that are involved between and among concepts.* (NCTM, 1991, p. 134)

There are a number of ways to engage teachers in learning mathematics content, including exploring within the context of adult-relevant mathematical activities, studying the use of rich problems with students so that students' thinking is exposed, exploring adult-level tasks that focus on content that is generally relevant to the mathematics content that teachers are expected to teach, and inquiring into cases of classroom practice that provoke the need for a deeper understanding of mathematical thinking that has occurred.

Knowledge of mathematics pedagogy

It often is noted that teachers teach the way they are taught; this should not be a surprise, given the fact that we build our world views from within the context of personal experience. Such a perspective justifies the maxim that professional development experiences must model appropriate pedagogy.

> *Mathematics and mathematics education instruction should enable all learners to experience mathematics as a dynamic engagement in solving problems. These experiences should be designed deliberately to help teachers rethink their conceptions of what mathematics is, what a mathematics class is like, and how mathematics is learned.* (NCTM, 1991, p. 128)

Teacher educators and staff developers need to model the approaches which they are promoting. This becomes more problematic as the directions for teaching shift to a constructivist view of learning. What does it mean to provide a constructivist environment in which to support teachers' learning as it relates to mathematics education?

> *It is increasingly evident that tenets of constructivism apply to adult learners. Learning is a meaning-making process which is personally constructed and impacted by experience, context, and the environment. Teachers need to continuously*

> *experience learning through problem solving and inquiry before they can own the process.* (Gregg, 1997, p. 217)

> *Just as mathematics instruction must be organized to facilitate construction of mathematical concepts, so should in-service instruction facilitate construction of a new pedagogical theory and practice.* (Schifter, Bastable, & Russell, 1997, p. 256)

Constructivist pedagogy extends well beyond the workshop. When teachers share personal experiences and particular struggles and triümphs, they acknowledge that this hard work is an important part of the process of change. This helps teachers see that the process of learning something new has ups and downs for everyone—themselves, their colleagues, and their students. Summer institutes and Inquiry Groups where teachers work collegially can provide a context in which they can learn to listen to another person's mathematical thinking and ask the questions that help one another stretch their thinking (Nelson, 1997).

Knowledge of students' mathematical thinking

Teachers' knowledge of content and pedagogy interacts with their knowledge of children. Knowledge of children and their mathematics is crucial to teaching mathematics for understanding. The changes in mathematics instruction proposed by the *Standards* (NCTM, 1989, 1991, 1995) require the development of professional and school cultures that support ongoing inquiry into how students' mathematical thinking develops.

In Cognitively Guided Instruction (CGI), Fennema and others have focused on how learning about children's thinking in whole-number arithmetic influences primary grades teachers' instruction, beliefs, and the learning of their children across all mathematics.

> *Knowledge of their own children's thinking enables teachers to make instructional decisions so that children's learning of mathematics improves.* (Fennema, Carpenter, & Franke, 1997, p. 195)

The structure of the professional development experiences in CGI engages teachers in doing activities which make it possible for them to consider a research-based model in relationship to children. A key component to this project is viewing videotapes of children solving problems and identifying relationships between the solution strategies and the problem types. Teachers are challenged to use children's solution strategies to predict how children will solve other problems. Eventually, teachers interact with their own students in a similar manner in order to make visible their students' thinking in ways that can be used to direct instruction.

Emerging from the work of this project and other similar projects (e.g., Campbell & Robles, 1997) is the expectation that teachers will reflect on the needs of their children and work with others to determine the activities, problems, or resources they need to use. Three possible approaches on how to do this surface.

> *One scheme is to make time available to examine and discuss examples of commercial materials that address mathematical topics appropriate for children. The second venue is to offer examples of activities or tasks, but always with another purpose in mind. For example, a problem may be offered as an illustration of how one could facilitate a child's re-examination of a mathematical construct. In another setting, a task may be presented, and the teachers may be asked to write questions that they could ask to determine what mathemaical ideas the children were constructing as they completed the task. A third approach is to follow an adult-level mathematics session with the challenge to the teachers to define a task that would address that same mathematical topic at a level appropriate for their students.* (Campbell & Robles, 1997, p. 184)

There also is value in structuring interview sessions with small groups of children (Gregg, 1997). While one teacher interviews students to probe their thinking about a specific mathematical idea, a second teacher observes and records responses. As the teachers learn about the conceptions children hold and how children think, they increasingly are willing to restructure learning experiences in their own classrooms, engage in dialogue about the results, and continue to work to improve instructional practice. At the same time, they may well deepen their own understanding of mathematics.

One way to connect the three components of mathematics teaching

Decisions about mathematical content emphasis, pedagogical strategies, and so on may be quite dependent on the nature of the curriculum being used. There are a number of possible critical focal points (e.g., curriculum, pedagogy, assessment) that could serve to "ramp up" our capacity for professional development. Cozzens and Robinson (1994) make an excellent case for the use of curriculum. Indeed, the choice of curriculum may well set the context for what is valued as mathematics and mathematics pedagogy.

Curriculum can serve as a tool for professional development (Russell, 1997). While there are several views of what constitutes a mathematics curriculum, one of the more productive views is that the best mathematics teaching environment is a partnership between teacher and curriculum.

> *The link between curriculum and teacher decision-making is a focus on mathematical reasoning. Neither curriculum nor teacher can fully anticipate the complex and idiosyncratic nature of the mathematical thinking that might go on among thirty students in a single classroom during any one mathematics class. However, both teacher and curriculum contribute to a repertoire of knowledge about student thinking that leads to better mathematics teaching and learning.* (Russell, 1997, p. 248-249)

The best use of good curriculum materials may well be in the context of a long-term staff development program in which teachers engage in ongoing reflections about their students' mathematical thinking and about their own continued work with their colleagues around mathematics content. Curricular materials can be a vehicle for ongoing teacher development that may be used to help deepen teachers' knowledge of mathematics content, of children's mathematical thinking, and of new pedagogical approaches.

Acquarelli and Mumme (1996) emphasize that professional development needs to be grounded in classroom practice. The ability to tie professional discussions and examination to what's going on in classrooms gives teachers opportunities to grapple with what reform is all about. Focusing the talk on curricular units appears to be particularly helpful to the process. Curriculum not only allows teachers to be exposed to big mathematical ideas in coherent, practical-sized chunks, it also becomes a tool for investigating problems of practice.

Factors that Influence Professional Development in Mathematics Education

Time for change and for reflection, collaboration, and inquiry

Learning to create the kinds of teaching envisioned by mathematics reform takes a *long time* and is hard (Ball, 1997). It is possible to characterize a developmental perspective within which to frame change as a process through the Concerns-Based Adoption Model for describing teacher change (e.g., Hall & Hord, 1987).

> *People undergoing change evolve in the kinds of questions they ask and in their use of the change. In general, early questions are more self-oriented (what is it? how will it affect me?); when these questions are resolved, questions emerge that are more task-oriented (how do I do it? how can I use these materials efficiently? how can I organize myself? why is it taking so much time?). Finally, when self and task concerns are largely resolved, the individual can focus on impact: is this change working for my students? Is there something that will work even better?* (Loucks-Horsley, 1997, p. 135)

Such a developmental perspective has implications for professional development in mathematics education (Loucks-Horsley, 1997; Friel & Gann, 1993). Clearly, it is important (a) to attend to where people are and to address the questions they are asking when they are asking them, (b) to pay attention to implementation over several years because of the transitions people need to make between resolving earlier concerns and moving forward with newer concerns, and (c) to create realistic expectations in the system for change.

Change is a process not an event. Such a view suggests that as teachers change, their visions of the teaching and learning also change. Implicit within this context is the need to address ways for teachers to collaborate and/or reflect together about teaching and learning mathematics in order to facilitate the process of change. A key component to facilitating such collaboration and reflection is having the *time* to plan for teaching and learning. The need for adequate time to teach and time to learn (plan, collaborate, reflect) appears at the top of most teachers' lists of roadblocks to carrying out proposed reforms in mathematics education.

The majority of teachers carry out their practice in isolation from one another; the often-expressed need for collaboration points to the issue of isolation. Working collaboratively can promote and support teachers in their inquiry into their practice of mathematics teaching and their efforts to change their practice and, simultaneously, to reflect on the impact of changes made. The kind of teaching that is now proposed with respect to mathematics requires a greater investment on the part of the teacher in the instructional responsibility and also entails a greater need for collegial cooperation (Schifter, 1997). There are a variety of strategies that may be used for promoting reflection, collaboration, and inquiry, a number of which have been noted earlier in this article.

Teachers' involvement in their own professional development and teachers' involvement through teacher leadership activities.

It is important that teachers have a central role in making choices and planning agendas with respect to their professional development in mathematics education. While it is evident that teacher development may be especially productive when the teachers are in charge of the agenda, such a stance raises concerns that revolve around what might be characterized as "the blind leading the blind." What is the role for teachers (and other school personnel) and for "experts" in making decisions about the nature and content of professional development?

One way to address this need is to help teachers develop a preliminary understanding of new directions in mathematics education before initial planning efforts are implemented. In one project (Bright, Miller, Nesbit, & Wallace, 1997),"visioning" sessions were conducted prior to the teachers' carrying out needs assessments of the mathematics programs at their respective schools. The intent was to expose teachers to such change efforts as those proposed by the NCTM *Standards* (NCTM, 1989, 1991) and to provide them with opportunities to engage in one or more situations in which they experienced mathematics in a way that modeled the directions detailed in these *Standards*. The purpose was to help teachers broaden their views about what is good mathematics instruction so that they could better assess both their programs and their needs in light of this vision. Once they had participated in the visioning sessions, teacher leaders spent time assessing their needs at the school level with respect to mathematics education and, using their needs assessments, developing school improvement plans. The school improvement plans became the basis for planning the content of the summer workshops.

Still others argue that there is an important place for outside experts in helping to initiate and lead change efforts.

> *Ongoing involvement of nationally recognized experts strengthens and enriches every aspect of reform projects. Consultants ... have the capacity to be objective about local conditions which impact the success of reform. Outside change agents are free to challenge ideas and practices and offer constructive suggestions from a national perspective.* (Gregg, 1997, p. 219)

It may well be true that such change agents, working with district decision makers and removed from internal politics, may be able to more easily challenge existing structures and practices.

In part because of the limited capacity in terms of people available to support teachers in working toward reforms in mathematics education, and in part because of the importance of making changes that are congruent within a school culture, the use of specialists of many sorts seems to be emerging as a key to successful efforts in schools (Ferrini-Mundy, 1997). Specialists (e.g., teacher leaders, mentor teachers) may be involved in spreading ideas, facilitating communications among teachers, initiating and planning staff development, and addressing political problems with administrators and community members.

Teacher leaders can play two roles in their schools. First, they can model quality mathematics instruction in their own classrooms. Part of the professional development that helped them become leaders should have helped them understand not only characteristics of quality mathematics instruction but also ways of implementing that kind of instruction. By inviting others to watch them teach, teacher leaders can provide images of what quality instruction looks like. Second, teacher leaders can encourage their peers to reflect on their own instruction in order to identify its strengths and weaknesses. Teacher leaders can explain model processes that are helpful in making such reflections, and they can also act as "sounding boards" when their peers try to do that reflecting.

In developing the capacity for teacher leadership in mathematics education, one of the dilemmas is how to identify those who will be leaders. A caution may be raised about identifying teacher leadership candidates too early; teacher leaders often "emerge" as part of a process of professional development. Those who do emerge are teachers that often have credibility with their peers and also demonstrate that they are willing to take risks and push for deep-level mathematics restructuring in their own classrooms. The ability to tap into their own classroom experiences provide leaders with "personal memory tapes" of the practical, as well as the pedagogical, issues related to implementation.

Leadership projects often highlight the importance of teacher teams. Parker (1997) identifies two major reasons why change agents should work in teams. The first addresses the concerns of expertise. Teacher teams that are cross-grade level permit leaders to articulate connections between grade levels and, for that matter, between school levels, assuring that consistent and compatible practices are being promoted overall. "Second, restructuring efforts that result in classrooms, schools, and districts aligned with the NCTM Standards are long-term, involve many unanticipated surprises, and can often be messy, uncomfortable, and frustrating for both participants and change agents" (Parker, 1997, p. 244). Teachers, as change agents, will benefit from the support that comes from working in teams as they work to understand and communicate the complex dynamics involved in change efforts of this magnitude.

Support within the context of the school and through on-going professional development.

Teachers work within both the school/school district and the community. This context includes not only the space and resources provided by the school district but also the students, parents, administrators, testing practices and policies, and district and state curricular objectives and guidelines. Context may be viewed as a "systems concern," that is, the success of professional development depends on simultaneous attention to changing the systems within which teachers work (Loucks-Horsley, 1997). If change is to happen, it is the systems in which teachers live and work that must be aligned and strengthened.

Not only does a school function within a community, it also is an involved and informed community itself. Large-scale teacher change in mathematics education occurs by school, not by individual(s). Being a member of the school community matters, and attention to the culture of the school is an important component of change. There is no doubt that "empowered" teachers of mathematics returning to "unempowered" environments often experience set backs and defeats. Teacher learning is both an individual and collective community activity, and lack of support and isolation make growth and change very difficult.

Teacher leaders can often act as bridges between individual teachers and the school community. They are typically perceived by the other teachers as "one of the," since they are, after all, part of the instructional staff. At the same time, in their leadership roles, they have contacts with school administrators and outside experts. Teacher leaders can view the school's environment from both the "top down" and the "bottom up."

The importance of both principal and parent involvement with respect to the changes being made cannot be over-emphasized. The principal's role should be that of instructional leader.

> *Active participation is necessary if principals are to be knowledgeable of mathematics reform goals, able to distinguish between classroom practices consistent with and inconsistent with those goals, understanding of the change process, prepared to support teachers' risk taking and growth through periods of confusion and discouragement, and able to effectively communicate the necessity and goals of mathematics reform efforts to parents and to teachers.* (Parker, 1997, p. 239)

Attention to community involvement may range from notes home and parents' nights to formal committees involving parents in making decisions about the goals of a mathematics program (Ferrini-Mundy, 1997). Better articulation of what needs to be done and how to do it in the context of systemic attention to school and community involvement is essential in supporting successful professional development efforts.

In addition to the support of school and community, the role of continued professional development in the form of long-term support cannot be over-emphasized (Ball, 1997; Loucks-Horsley, 1997). There are a variety of ways to plan for such support, including, but not limited to, helping teachers to reflect on their practice, building networks through which teachers can learn from each other, maintaining the focus of a staff development program for a sufficient duration so that teachers can internalize the change, helping teachers overcome less-than-optimal conditions that may work against their continued development once they return to their school, facilitating discussion and communication among teachers, providing time for someone to visit and support what is happening in the school, and providing a sounding board for issues and concerns. On-site support appears to be a critical aspect. This may be provided in a variety of ways, including by someone in the building such as a teacher leader or some other designated person or group, a team partner who might be at another school, electronic teaming, and so on. As Bush (1997) notes, a successful teacher enhancement project should use professional development models which include mentoring, peer coaching, team teaching, and reflection.

There continues to be a lack of clarity, however, about what constitutes "effective support." While many projects engage in long-term support, it has been difficult to capture the essence of this support from written descriptions. For example, what does a support person do when making classroom visits? Is there some developmental process that provides insights into when the use of such strategies as demonstration teaching or coaching may be appropriate? How do we better understand the dynamics of informal support as provided by teacher leaders? The list of questions goes on and on.

Conclusion

It seems that the events that begin a project need to meld into the building of a community that provides support for changes in mathematics teaching in a variety of ways. Part of the building of a community involves making explicit the beliefs about mathematics teaching and learning of everyone in the community. Visions of possibility with respect to the components of mathematics teaching may be created in inservice courses or institutes by focusing on knowledge of mathematics, pedagogy, and students' mathematical thinking as a framework. But the realities of implementation happen in teachers' classrooms with their own students in their own schools. As teachers work to make changes in practice, they encounter innumerable issues and concerns that could not be predicted, much less addressed, by earlier inservice work. The debriefing of these issues and concerns can be tied to discussion of changing beliefs and discussion of the three components of mathematics teaching. A community that supports the visions of change is necessary if teachers are to address the questions and challenges that arise and be encouraged in their continued efforts to make the changes in mathematics teaching and learning that are needed.

References

Acquarelli, K., & Mumme, J. (1996). A renaissance in mathematics education reform. *Phi Delta Kappan, 77*, 478-484.

Ball, D. L. (1997). Developing mathematics reform: What don't we know about teacher learning–but would make good working hypotheses. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 77-111). Lanham, MD: University Press of America.

Bright, G. W., Miller, A. C., Nesbit, C. R., & Wallace J. (1997). The role of curriculum in teacher development. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 165-172). Lanham, MD: University Press of America.

Bush, W. S. (1997). The Kentucky K-4 mathematics specialist program. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 173-177). Lanham, MD: University Press of America.

Campbell, P. F., & Robles, J. (1997). Project IMPACT: Increasing the mathematical power of all children and teachers. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp.179-186). Lanham, MD: University Press of America.

Castle, K., & Aichele, D. B. (1994). Professional development and teacher autonomy. In D. B. Aichele & A. F. Coxford (Eds.), *Professional development for teachers of mathematics* (pp. 1–8). Reston, VA: National Council of Teachers of Mathematics.

Corwin, R. B. (1997). Talking mathematics: Supporting discourse in elementary school classrooms. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 187-192). Lanham, MD: University Press of America.

Cozzens M. B., & Robinson, E. (1994). Implementation of standards-based curricula. *ESIE Access*, pp. 1-2.

Fennema, E., Carpenter, T. P., & Franke, M. L. (1997). Cognitively Guided Instruction (CGI). In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 193-196). Lanham, MD: University Press of America.

Ferrini-Mundy, J. (1997). Reform efforts in mathematics education: Reckoning with the realities. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 113-132) Lanham, MD: University Press of America.

Friel, S. N., & Bright, G. W. (Eds.). (1997). *Reflecting on our work: NSF Teacher enhancement in K–6 mathematics*. Lanham, MD: University Press of America.,

Friel, S. N., & Gann, J. H. (1993). Making change in schools. *The Arithmetic Teacher*. January, pp. 286-289.

Gregg, L. (1997). Mathematics and science enhancement (MASE) project. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 215-222). Lanham, MD: University Press of America.

Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process*. Albany, NY: SUNY Press.

Laurenson, D. J. (1995). Mathematics and the drift towards constructivism: Are teacher beliefs and teaching practice following the beat of the same drummer? *NCSSSMST Journal. 1* (2), 3-7.

Loucks-Horsley, S. (1997). Teacher change, staff development, and systemic change: Reflections from the eye of a paradigm shift. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 133-149). Lanham, MD: University Press of America.

Loucks-Horsley, S., Hewson, P. W., Love, H. , & Stiles, K. E. (1998). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press, Inc.

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics (1991). *Professional standards for teaching mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics (1995). Assessment standards for school mathematics. Reston, VA: Author.

Nelson, B. S. (1997). Mathematics for tomorrow: Systematically-embedded teacher enhancement. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 229-235). Lanham, MD: University Press of America.

Parker, R. E. (1997). Comprehensive school and district restructuring of mathematics principles and caveats. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 237-246). Lanham, MD: University Press of America.

Russell, S. J. (1997). The role of curriculum in teacher development. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 247-254). Lanham, MD: University Press of America.

Schifter, D., Bastable, V., & Russell S. J. (1997). The role of curriculum in teacher development. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in mathematics K-6* (pp. 255-261). Lanham, MD: University Press of America.

5 Designing Programs for Teacher Leaders: The Case of the California Science Implementation Network

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Teacher leadership development programs require careful design if they are to meet the challenges of today's science and mathematics education reform initiatives. This chapter describes the design of one such program using a design framework developed to plan and analyze effective professional development programs. The program, the California Science Implementation Network (CSIN) develops teacher leaders to assist their schools and others to improve the quality of their science programs. CSIN's context, the knowledge and beliefs that influenced their design, the strategies they use, and the issues they face, are discussed in detail in the chapter. A vignette of a school district participating in CSIN illustrates how teacher leadership grows and functions in one setting.

Programs for teacher leaders face an enormous challenge. Although these programs work hard to support the development of new knowledge, skills, and dispositions for teachers taking on roles as leaders, they must simultaneously attend to issues of classroom teaching, of school and district development, and of policy implementation. Thus, designing programs for teacher leaders is somewhat more complicated than doing so for teachers—and it often occurs under enormous pressure to transform teaching and learning and do so with backbreaking timelines. Without teachers taking on leadership roles, helping increasingly more teachers to grow and change, there is no hope that our current reforms will achieve their ambitious goal: strong science and mathematics learning for *all* young people.

It is in this context that an ambitious teacher leadership initiative began in California, and has grown and been sustained for over a decade. This chapter describes the California Science Implementation

Network (CSIN), a professional network that has evolved from its focus on elementary school science to extending across the curriculum and into a partnership with other programs that now stretches across K-12 as the California K-12 Alliance. The story of CSIN and its work in teacher leadership is told here by its current director and its one-time formative evaluator—a partnership through which both of us have learned a great amount over time. Here we use a framework developed by the National Institute for Science Education (Loucks-Horsley, Hewson, Love, & Stiles, 1998) to describe and analyze CSIN's design for leadership development, to point out unique features of the design that appear to contribute to the network's success and issues with which we both continue to struggle. We have chosen to use the first person in this chapter, for it emphasizes the life and dynamism of the network. However, the voice is that of CSIN's professional developers,[1] with their evaluator in the less active role of "participant observer." Who benefits most directly from CSIN's teacher leadership program? Before we describe CSIN's design for developing teacher leaders, we introduce four of them.

The Power of One!

Ten years ago, four teachers left their classrooms and schools to attend a science education leadership development program sponsored by CSIN. The goal of the program was to develop teacher leaders who could assist their schools in designing and implementing quality science programs. The four teachers had a variety of backgrounds, but all enjoyed science and wanted their students to have interesting, engaging, and challenging science experiences.

Kim was a quiet, experienced teacher, in the same district for over 20 years. She cared about her students and worked hard at preparing a positive, academic curriculum. Kim had never been a leader in her school or district, but was respected by her colleagues as a competent teacher. When the district was ready to improve science, Kim was selected as a lead teacher from her school to join teachers from four other schools at the science leadership training. When she arrived, she was overwhelmed at the quality of participants.

They knew much more science than she, seemed much more articulate, much more "together." She never really viewed herself as a

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[1] The authors appreciate the contributions of CSIN staff members Cindy Anderson, Karen Cerwin, Diane Dooley and Phil Lafontaine.

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leader. The leadership program, however, required Kim to build on her strengths and partnered her with others to address her shortcomings. Kim found a place to learn, to grow, and to spread her wings. She returned to the network for several more years. She took on increasingly complex tasks in the professional development program, designing and delivering many sessions. Yet, something was lacking: over the years, she had difficulty bringing others along and eventually, her district officially dropped from the program. District administrators and her colleagues still view Kim as competent and have continued to ask her to conduct science workshops and serve on district committees to decide policy issues.

Jose, like Kim, was an excellent teacher. He was a science specialist at his school and everyone was thrilled to have him on staff. He was enthusiastic and an example of a "life-long learner." He attended the leadership development program for several years and assumed the role of a staff developer to work with several schools. The catch—none of these schools were from his district. He was not perceived as a "prophet in his own land" and try as he may, he was only able to move his own school forward. Jose looked for other ways to use his knowledge of science and his leadership skills. He became interested in statewide assessment through his work with CSIN and is now working with an assessment project to develop assessments and train people in their use nationwide.

Teaching science in the middle grades was Gail's love. She was good at it and had the support of parents, colleagues, administrators, and students. The school sent her to be their representative at the California Science Project (CSP). CSP collaborated with CSIN for all of their leadership training. Gail came with the skills of an excellent teacher, but no idea how to work with adults, design professional development, change schools, etc. The network leadership program developed these skills. As a staff developer she had to design professional development sessions that addressed content as a "conceptual flow" and inquiry as a reflection of questioning strategies, and use a questionnaire assessing teachers concerns to determine appropriate interventions. Then Gail had to conduct these sessions at a lead teacher institute. And she came back year after year to refine these skills, gain new insights, and address new challenges. Gail now directs a regional professional development program for K-12 teachers built on the principles she learned in the network. Yet science at her district is still uneven.

Brad taught in a medium-sized suburban district in Los Angeles County. In 1988, he volunteered to participate in CSIN based on his interest in improving science instruction in his 4th grade classroom. Little did he know that his participation in the network would lead to opportunities far beyond the classroom. Through CSIN professional development opportunities, Brad was able to choose leadership paths within his school and district, region, and within the state. On his leadership journey, Brad assumed a number of roles from lead teacher, to staff developer, and a cadre member. In these roles, Brad not only delivered the work of the network but also provided essential feedback to the organization, informing many of the practices and decisions of the network. Brad's district realized the importance of his work and eventually created a new position at the district level that included responsibility for all science programs and science professional development. Over a ten-year period, the district has institutionalized inquiry-based science in all of its schools and has an ongoing professional development program to support science.

What is Leadership?

Of the four teachers profiled above, who is the teacher leader? By our definition, they all are. These four teachers share several things in common: they had a desire to take action on something they cared about; they were empowered at some level to make change; and they have the knowledge, skills, and stamina to lead. These three themes occur and re-occur when one looks at successful leadership. Kim had a personal transformation and was able to share information with others. Jose spread a "thousand points of light" that caused others to think and re-think the impact of their science program on student achievement. Gail came as one teacher and influenced an entire region. Brad led the institutionalization of a district for inquiry-based science.

Our certainty from many leadership development experiences that leadership is key to reform is validated over and over again in the research on professional development and educational change. Michael Fullan (1991) and Rodger Bybee (1993) point out that leadership and support are required for professional development experiences to be actualized as changes in teaching and learning. But what is leadership? What does it mean to be a teacher leader? We recognize that leadership means different things to different teachers. Some teachers embrace it, while others avoid it at all cost. Few seem neutral to the concept. If we believe that developing teacher leadership builds capacity, then we as leaders of reform must understand how leadership is viewed and how our constituents define it.

David McClelland (1970) suggests that people are driven to leadership by at least one of the following motives: (1) achievement—the desire to complete tasks and accomplish goals; (2) affiliation—the desire to be liked and to share in positive relations; and (3) power—the desire to exert influence. Many educators—particularly teachers—can identify with the first two and shy away from the last motive. In large part this is due to our negative stereotypes of power that have led us to equate it with being a bully, with dominance, and with arrogance. Yet McClelland reminds us of another face to power—that of empowerment. Harvey and Drolet (1994) suggest that the most effective approach to leadership focuses on others and emphasizes the growing competence of everyone in the organization. "Empowerment is the art of increasing the competence and capability of others by endowing them with a sense of self-worth and potency" (p. 163).

Julian Weisglass, (1994) a mathematics professor at the University of California, Santa Barbara, eloquently describes leadership as "taking responsibility (action) for something you care about" (p.1). This may or may not be done on a large scale; its impact may be huge, or minimal; it may be complex or deceivingly simple. No matter. When the action is something near to your heart and soul, the action has a chance of succeeding. When you are responsible for something you don't care about, the work at best is half-hearted and at worst is reckless, a waste of time and establishes a downward spiral for the intervention.

What are the characteristics of effective leadership?

Information is power, Margaret Wheatley. Our view of leadership is broader than many other views because we recognize that being a good teacher is not the same thing as being a good leader and working with adults is not the same as working with students. Certainly, we need teacher leaders who are knowledgeable about science content, instructional strategies, and student achievement. But it goes further. A teacher leader must facilitate change with their colleagues through their roles as trainers, coaches and consultants. Additionally, teacher leaders must develop expertise in organization design, change theory, adult learning, management skills, decision making, public relations and handholding. Change is, after all, a people business.

A leader is a dealer in hope, Napoleon Bonaparte. Characteristics such as having vision, being persistent, having a sense of humor, and welcoming diversity enable leaders to radiate the possible. Leaders who are knowledgeable and have practical experience are credible. And credibility lends itself to confidence. Leaders with both traits move people. A leader driven by passion will succeed in expanding energy to get the job done. A leader's vision must be vital, exciting, and clear. And it must communicate the "I can" (of course with support!) philosophy. Leaders who sense opportunity rather than danger, empower rather than control, and develop rather than maintain, enable people and organizations to pursue their dreams.

To lead people, walk behind them, Lao-Tzu. Although leaders are often recognized for being in front, true leaders know how to support from behind. These leaders balance guidance with independence, vision with reality, leading with following, authority with shared decision-making, "stardom" with partnerships. Effective leaders are committed to the community. They recognize that no one person can do this by him or herself.

Leaders must be stewards, both for the people they lead and for a larger purpose that benefits all, Senge (1990) Stewardship is also a trait that is common among successful leaders. They see the need to give back to the system—to nurture and mentor the budding leaders and to provide support for their learned colleagues. They develop or participate in networks to share ideas, successes, and challenges. They see the need for collaboration and recognize that there is much more to do than any one person could accomplish. On a daily basis, they live the idea that the whole is greater than the sum of its parts.

Why is Leadership Development Necessary?

> *Leaders aren't born—they are made. And they are made like anything else through hard work*—Vince Lombardi.

We believe in a continuum model of leadership—not levels of leadership. Thus, you do not graduate to be a leader. Instead, you move along a pathway building knowledge, skills, and understanding because you are grounded in leadership practice in your daily life. And because leadership is a continuum, everyone can be a leader in some capacity. Everyone has some sphere of influence in which they can effect change. But they need to learn how to do it and they need support.

Building capacity does not just happen. It is the result of carefully designed professional development programs, divine providence, and just plain luck! As Karen Worth (in Loucks-Horsley et al., 1998) notes, "you plan for where you want to go and then meander towards it" (p. 248). But what do you consider as you plan an initiative, in particular, the development of responsive, empowering leaders?

Designing Programs for Developing Leaders

A framework for design can help think about development programs: those for leaders as well as those for teachers. Several years ago, the professional development team of the National Institute for Science Education (NISE) set out to research effective professional development for teachers of science and mathematics. Collaborating with experienced and well respected professional developers from all over the country, we soon discarded our search for successful models, realizing that, like effective teaching, effective staff development is an ongoing and ever-changing process of design. Good professional developers, like good teachers, begin with a set of goals based on the needs of teachers and the students they teach; consider the particular constraints and resources of the educational context, and draw on knowledge and strategies from research and best practice to create the most responsive, and consequently unique, program or initiative for the particular setting. A design framework, depicted in Figure 1, illustrates the parts of the design process and the elements that warrant consideration if the design is to be successful (Loucks-Horsley et al., 1998).

The design framework can be used in several ways (Mundry & Loucks-Horsley, 1999). It can be used to guide actual design of programs and initiatives, to analyze and then improve existing programs and initiatives, and to understand why and how a program failed or succeeded. Also it can be used as an analytic tool after the program has ended to describe a program and how it seeks to pay attention to all of the processes and elements of design. It is this last way that we use the framework in this article: we describe how leadership is developed by CSIN to pursue its mission to assist districts, schools, and teachers to transform the education of their students. CSIN's leadership development program is an example of a robust, broadly reaching initiative whose design pays careful attention to the many elements needed for professional learning and change. In the sections below, we describe this leadership development

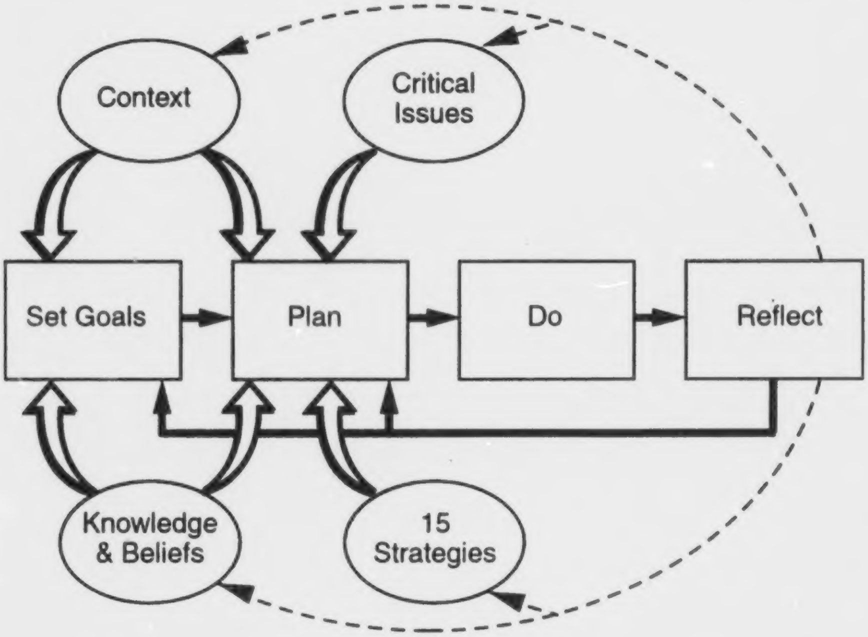

Figure 1. Design Framework

program using the elements of the professional development design framework.

Context

Context is a key influence in the design of professional or leadership development initiatives. Expectations set by states, districts, schools, and communities; the nature of the student and teacher population; the human and financial resources available to education; these and many more factors affect the goals and strategies used in the design. In the case of CSIN, the state context was critical because it set important expectations for teaching and, consequently, for the roles of leadership.

In the early 1980s, California began major educational reform in all curricular areas. By the early 1990s, California had put a model of systemic reform into place that included: 1) curriculum frameworks which formed the foundation for reform; 2) state-adopted instructional resources based on the philosophy of the frameworks; 3) statewide "authentic" assessment aligned with the content and pedagogy of the frameworks; 4) program quality reviews for a school's self study of the effectiveness of their mathematics and science programs; and 5) statewide leadership development networks in mathematics and science.

California applied for and was awarded a National Science Foundation (NSF) statewide systemic initiative grant in 1992. The California Alliance for Mathematics and Science (CAMS) had professional development as a major strategy for systemic reform. The plan built on two prototype teacher networks and expanded them statewide. These networks, the Mathematics Renaissance and CSIN were school based, designed to create a capacity at the school level to implement the reform. The networks were strategically targeted at grade spans that acted as "gatekeepers, rather than gateways" for all students. Thus Mathematics Renaissance focused on middle school mathematics reform, while CSIN addressed reform for K-6 science. Because of California's size (e.g. 6,500 elementary schools), direct professional development for all teachers was not feasible. Instead, each network worked with a "tip-point" strategy that assumed that by involving 20-30% of the state's schools in the reform, the scale would "tip" and the other schools would follow suit in pursuing the reform agenda. As part of this strategy, the networks developed teacher leaders who, in addition to working with their schools or clusters of schools, became members of committees, in which statewide policies were made.

CSIN actually began in 1988, prior to the NSF funding, as a fledging teacher leader network with one statewide director, 25 teacher trainers (science staff developers) and 50 schools. Over its 11-year history, CSIN (with NSF funding) grew to 12 regional directors and over 200 staff developers (classroom teachers who work with multiple schools). In the process, CSIN has assisted more than 1700 elementary schools to plan and implement quality science programs, and it has influenced how schools operate—from finances to teacher collaboration to student learning. CSIN has helped develop the leadership capabilities of more than 2000 teacher leaders.

CSIN has recently joined with two other reform initiatives to form the K-12 Alliance (California Science Implementation Network [CSIN], Science partnerships for Articulation and Networking [SPAN], Scope, Sequence and Coordination [SS&C]). The Alliance follows the CSIN model as it builds a school's capacity for initiating and implementing change in science programs through a 21-day year-round professional development program that focuses on content, use of instructional materials, pedagogy, and leadership. A school may enroll yearly, but schools are encouraged to participate for three to five years. (Evaluation indicates that a three-year involvement increases the likelihood that change will occur and be sustained.) The program is designed and continuously reviewed and refined, based on local needs and impact data from the participants and their students. The development of school capacity and the leadership required to maintain it is based on knowledge and a set of beliefs that combines the "wisdom of practice" and research findings related to leadership, pedagogy, science content, and the change process. This knowledge base influences how teachers are nurtured to be leaders, through appropriate and varied strategies for learning and leadership development. The design is juxtaposed against a number of critical issues that staff have determined need to be attended to if an initiative is to succeed.

Knowledge and Beliefs about Leadership

We are a society that operates from knowledge and beliefs—whether it be the type of car we drive, the politics we support, the jobs we continue to do and the causes for which we volunteer. Our actions within the educational system are no different. Our view of professional development—from the amount of time we devote to the effort, to the impact we try to have—is guided by what we know, what we understand, and what we believe. Knowledge and beliefs are a critical component of the design framework and influence both the goals and the planning of every initiative.

The CSIN program, like many others, began with a "heart" to do the right thing. Much of the early influence in design was based on what motivated people—rather than what made good science. (Soon afterwards, however, we understood the need to balance our attention to motivation with care in providing strong and deep science content and pedagogy to all teachers so they in turn could do so for their students.) We began intuitively—believing all along that teachers were and are professionals who make wise choices and want to improve their way of teaching for the good of children. We did not begin with a deficit model. We were not trying to fix what was broken. We were looking for what was—and how to make it more effective, more efficient and more productive for teachers and students.

Instinctively, we knew that professional development had to look holistically at a system—thus, we targeted school-wide change.

Although teacher-by-teacher change is valuable, it simply cannot get the job done in a timely manner. More importantly, current research would underscore that teacher-by-teacher change is less effective for reflection and continuous improvement (Loucks-Horsley et al., 1998). We knew that the professional development program had to include a variety of intensities to meet teachers where they were and move them along a continuum. Our slogan became—there is no "done"! Everything is continuous improvement. We enveloped the notion that everyone had something to contribute and thus became—although the word was not yet in vogue—a community of learners. We just knew we could learn from each other—that no one person had *the* answers. Our job was to pick quality people who had potential, remove their roadblocks and then get out of their way!

We knew enough of McLaughlin's (1993) work on teacher networks to recognize their power for developing teacher competence and confidence in learning and teaching science *and* in providing long term support to change a teacher's belief and practice. And we also knew that we needed to listen to the field. If we were theory only, we would not survive. The movement had to be grounded in reality and responsive to the needs of the field.

Lastly, we valued leadership. We did not give in to "Monday morning science." We believed that building solid, credible leaders was key to implementation, replication, and scale up and so we boldly set our course of developing leaders. Like sailing to that distant shore, sometimes the sailing was smooth and we moved swiftly; other times we tacked for hours, trying to find the wind, and the right strategy. What we learned through the years is to truly value some of our early assumptions, to continue to add to our repertoire—and to never get too full of ourselves! We do hold these "truths" to be self-evident:

Leadership is a people business.

Although our scope of work is in the field of science reform, we believe that leadership involves setting a shared vision and translating that vision into reality. As such, leadership is about change—and the change process (Hord, Rutherford, Huling-Austin, & Hall, 1987) is people first, intervention second. As a network, we built on the strength of people by first honoring them as humans, second celebrating their professionalism as teachers and thirdly prompting their leadership by providing opportunities to stretch in a safe and supportive environment. Nurturing empowers.

Teacher leadership includes understanding science content, teaching and learning and organizational development and design and change theory.

We know that leaders have to be credible in order for people to "buy into" a vision! One area of credibility for science teacher leaders is their science expertise. Teacher leaders need to continually update and deepen their knowledge of science. No one can disagree with this statement but it provides lots of food for thought—how much content is enough for an elementary teacher leader without a science background? How much content is enough for a secondary physics major to teach high school biology? Yet we know that without content background, one can not provide the conceptual framework to challenge teacher understanding and delivery of content to their students.

Another area in which teacher leaders must demonstrate credibility is in understanding the dynamics of teaching and learning. They must be skilled at a variety of instructional strategies that increase student engagement and raise student achievement.

Although credibility in content and teaching and learning is important, a teacher leader in our program *must* go beyond their classroom and sharing their classroom expertise. They must be willing to learn how to help lead the organization. They need to support teacher efforts in the school, teaching and learning leadership in classroom practice, and supporting the leadership of peers. They also need to understand how to work with a variety of stakeholders. In order to do that, the teacher leaders must have knowledge of change principles and organizational design.

Leadership development is embedded in the daily work of the network and the daily work of the teacher leaders. Leadership develops with real work. Leadership capacity is built through performing leadership tasks such as working with planning documents (which include a Program Elements Matrix, Content Matrix, and Profile Instrument, forms created and used in the CSIN2 SSD Training manual developed by K. DiRanna and the Regional Directors from 1972-1977), designing and conducting community meetings, facilitating grade or department meetings, and presenting during institute. In other words, there is real work to be done. Unlike many programs that provide leadership services and ask participants to do "something" back at the home front, CSIN designed an extensive "on-site" program that lead teaches could adopt, adapt, or re-design to meet the needs of their staff. What they could not do was opt out of providing (with our assistance) between 25-50 hours of professional development for their colleagues.

Leadership has multiple entry points.

This was an unexpected learning! Our first year, we looked for the stars. Although we got some already polished leaders, we had many more dedicated souls who were interested in becoming leaders and willing to take risks. In the early days, we grew rapidly—and did not have time to reflect and build—it was often "sink or swim." And out of this came one of our most important values: Leadership is what you make it—so you get on the moving train and grow with us! We found that helping a hundred budding leaders yields a much larger garden than tending to one prizewinner. Having leaders in a variety of growth stages also indicated to participants that we were learning together. As expected, some of the workshop sessions were uneven and unpolished. But this had an interesting effect on participants. They had a sense that if person X can do Y, then maybe they could also try it. Leadership became contagious.

A Leader By Any Other Name

Readiness for leadership is determined by the individual, their school, and/or their district. The network takes who is sent because we recognize that power is often vested in school/district culture, and leadership, to be successful, must be tied into that power base. What this means in reality is that some participants might not have been selected if the criteria were determined solely by us. And if it was, often we would have been wrong. So our job became working effectively with a wide variety of personalities, knowledge and skill levels. We needed to constantly remind ourselves that leaders come in many sizes and shapes!

Leadership growth is non-linear.

Although we recognize that some believe that one "graduates" into leadership, we firmly believe that one evolves—slowly—*and* with punctuated evolution! Because we believe so strongly in "job embedded" leadership development, we designed programs that provide a variety of opportunities for people to lead. Many begin as a lead teacher representing their schools. They go on to practice their leadership in a variety of roles, with varying degrees of complexity—including staff developers who work with clusters of schools, cadres who help deliver the science content and regional directors who plan, and implement professional development programs. Many serve on district, regional and state level policy making committees.

Leadership development is a team sport.

Support, support, support! Our view of leadership is not a person on the white horse leading the charge. Instead, we think you can be a "prophet in your own land" if you just get off of the high horse! We view leadership as shared decision making (Fullan & Hargreaves, 1996). As such, we recognize that there is not a "mold" for leadership development. However, we also recognize that several models of leadership development can be analyzed for the effectiveness of a variety of components. Sharing through the network capitalizes on the experiences of others so that the whole is greater than the sum of the parts.

We also believe that resilient organizations are composed of leaders who embrace ambiguity and solve problems in novel ways. One cannot solve problems with the same solutions that made the problem. This requires extensive and intensive communication among colleagues and requires a school to see learning as a journey taken together.

The power of one translates into the power of many.

An organization can take on a life bigger than itself. Increased credibility of the individuals brings increased credibility for the organization and leadership opportunities begin to snowball. In other words, "birds of a feather flock together" and through the "tip-point" strategy, once a strategic mass moves toward a vision, the rest will follow.

Good work begets good work. Often this tip-point is accomplished by leaders who are recognized as credible, believable, and influential. Their words, or presence at meetings and conferences, is respected and listened to. Over the years we have evidence that, like E.F. Hutton, CSIN has been heard! Others began to spout the vision represented by CSIN. Another mechanism for moving the tip-point is following the influence of those who participate in the program, move onto other venues—but take the learning with them. CSIN has been particularly effective in having alumni take decision-making positions as school, district, and county administrators. A third mechanism for tipping the scales involves people who become familiar with the program through articles and adapt ideas to fit their own. CSIN and some of its strategies were listed in the 1990 California Science Framework, providing our work with a state "stamp of approval" . Many districts used the framework's chapter on implementation, which was written by CSIN, as their guideline for change.

The power of many also has a leadership dimension that involves the formation of partnerships and collaborations. The leadership strength of an organization can be measured by those who want to align with it because of its power—and those who want to squelch it because of its influence! CSIN has been in both positions. Throughout most of its history, organizations like Sandia National labs, urban and local systemic change programs, businesses and universities, have collaborated with CSIN. Recently, as the politics of California have changed, CSIN has become a "force to be dealt with" because of its influence.

Strategies

There is no limit to the strategies that can be used to help people learn. The design framework emphasizes that there are no "effective models" that can be selected and dropped into place—and expected to work regardless of the setting. Instead, each initiative requires a unique combination of strategies in order to address its goals and honor the knowledge and beliefs of its designers.

CSIN's knowledge and beliefs govern the way we think about developing teacher leaders and influence the strategies we use. We think about professional development as a continuous loop. We ground our design in the reality of what is happening in the field and determine how we might adjust to best influence it. This has required us to constantly reflect on our work and extend our strategies, building layers of complexity as we and our clientele become more sophisticated about implementing quality science education programs. We have never, in twelve years, offered the exact same program!

Here is what has proven effective: we have a statewide vision and implementation plan for the program that is similar around the state, with local variations. Although we respect and encourage districts and schools to help us plan professional development, they often are not certain about where to start. So we provide prototypes if they do not know what they need. We know they are developing well when they take some of our suggestions and revise them completely or even throw them out.

Over the years, CSIN has employed a variety of strategies for building leadership. Lead teachers, typically one per school, attend a 21-day program that addresses content, instructional strategies, and leadership skills. Lead teachers are also responsible for providing between 10 hours (first year leaders) to 50 hours (2+ year leaders) to their staff/district.

The 21-day program for lead teachers is designed during a 10-day leadership academy for staff developers. During this academy, staff developers have opportunities to hear from experts whose writing and thinking expands participants' views of leadership and their roles as leaders. They role play a variety of leadership situations, participate in case discussions about leadership, investigate new topics (e.g., data-driven decision making; facilitator toolkits), and design the 21-day program for the lead teachers. This design process involves selecting and creating the strategies to be used in the program and writing the "manual." The manual documents the thought, discussions, and scenarios that are involved in designing each session. It helps clarify the vision for the lead teacher program, helping staff developers extend their own understanding from their discussions with colleagues. The design of the 21-day program usually incorporates several strategies.

Content is taught by a three-member cadre consisting of a university scientist, high school science teacher, and either a middle school or elementary teacher, depending on the audience. The cadres teach conceptually, linking ideas through questioning strategies. Back home, lead teachers, with assistance from their cadres, help teach content to their school staff on seminar days.

Instructional strategies are presented through participation in lessons that focus on using the learning cycle, examining lesson design and questioning strategies, gathering evidence for student learning, fostering equity in science learning, using multiple measures to assess learning, using peer coaching, and using video cases to analyze teacher decisions.

Content, teaching, and learning are addressed through a collaborative teaching and coaching model that includes planning, teaching, reflecting on student work, altering the teaching plan, teaching the revised lesson, and reflecting again with student work. Regional directors facilitate collaborative teams of four. The collaborative coaching is continued over six days throughout the school year. The team focuses on using evidence of student learning to guide the lesson design, reflecting, and then redesigning the lesson. The student work is also used as part of professional development on assessment.

Leadership experiences related to organizational design and change theory include work with the Concerns-Based Adoption Model (Hord et al., 1987), dealing with change and resistance, building teams, using the Myers-Briggs (1962) style inventory, adult learning, facilitation skills, and professional development design.

After their 21-day program, lead teachers provide professional development at their school sites, based on the needs of their school staff. They are assisted in design and delivery of these sessions by staff developers and regional directors.

Critical Issues of Leadership Development

The design framework cautions professional developers to pay attention to certain issues or they may undermine the success of their initiatives: the warning is, "ignore them at your peril." Over the years, CSIN has identified several issues that are critical to the network's success. Unlike problems to be solved, these issues are too complex to eliminate, but are in constant need of attention and creative ways to deal with them.

School Culture

Fullan and Hargreaves (1996) talk about the influence of the school culture on its ability to set visions and work toward achieving the vision. They talk about balkanization of faculties where groups practice "one-ups-manship." As the joke says, a consultant is anyone who is at least fifty miles from home. Yet we know that building capacity in schools requires collaboration and shared leadership, so an issue for schools is how to use shared decision making to break the stereotype of not being a prophet in your own land. Can collaborative problem solving encourage teachers and schools to change from self deprecating to self enhancing? Can a school that sees learning as a journey taken together, promote excellence among all staff—enabling each of them to take leadership responsibility for what they care about? Building collaborative cultures that value initiative, expertise, and feedback is a challenging goal for CSIN.

Leadership is politics.

Both "leadership" and "politics" are loaded words, and arenas that many teachers avoid. Yet the reality in education is that everyone wants to tell educators what to do, to spell out their future. The only way to make sure it is a future teachers want, is to take the initiative and plan it themselves! This of course means that teachers and teacher leaders have to look beyond their sphere of influence—beyond their classrooms, and often their schools and districts—and recognize that they have the possibility to influence others.

Backfilling Leadership

Leadership is hard work and it takes its toll—whether due to burn out, new opportunities, fleeting glory, or sharing the limelight. Burnout is a major detractor to maintaining a large pool of teacher leaders. In part, this is by definition—a teacher leader is also in the classroom and so automatically has two full-time jobs—teaching and leading! Even under the best of circumstances, this is exhausting.

Additionally, budding leaders who are good and want to excel can find plenty of work. Unfortunately, they frequently do not know how to prioritize, which relationships to build, or how to say no. They take on too much, worrying about being left out if they do not participate, and prefer to do things themselves. All of these syndromes can contribute to failure.

For successful leaders, new opportunities spring everywhere. And unfortunately, when the leader leaves, the program often collapses. One reason this happens is that there is no organizational thinking that keeps the leadership pipeline open, flowing with new people and new ideas. An organization can stagnate because there is no pathway for leaders to grow. As successful as CSIN has been, there are limitations to its infrastructure. Funding limits the number of full-time positions and thus limits the number of leadership opportunities. Many CSIN leaders have had to take other leadership positions outside this organization. Of course, this ultimately benefits the network, especially when the person assumes a position of authority, often as an administrator, and can still participate in and support the network. CSIN has addressed the issue of limited leadership positions by creating new ones. For example, the staff developer position in the cadres originated as a way to keep talented staff developers in the program, even if their schools had decided to focus on content areas other than science.

Backfilling leadership also means sharing the spotlight, the stage, the fame, and the status. In some cases it means giving up control. There is a personal issue to determining how much mentoring/nurturing one gives. The question could be: how far can I promote you without losing my own status? It takes a highly mature, competent, and confident leader to transcend this personal concern. Nurturing leadership, building competence and confidence, providing multiple pathways for leadership, and planning for succession are all important issues. This is especially true given the "graying of leadership"—nurturing young, new leaders is a constant challenge for CSIN.

Developing Leaders Among People of Color

Equity at all levels of the education system—from students through the highest levels of leadership—is a particular concern in science and mathematics. Everyone should have equal access to positions of leadership, as long as they can demonstrate the readiness to learn and the willingness to spend the time and effort it takes to do so. Yet, just as there are insufficient teachers of color for our classrooms, so there are even fewer leaders among people of color. CSIN constantly struggles to fulfill its commitment to mirror the diversity in California in its teacher leaders. The network has found some success in using a combination of aggressive recruitment, strong mentoring, and the use of role models. Yet many questions remain, What approaches and styles best welcome people with diverse backgrounds into a community? Is a critical mass of people of color necessary before others are inclined to step forward? and What components can be added to programs to help people learn how to think deeply about issues of diversity and strategies that promote it?

Scaling Up

CSIN has faced the issue of going to scale from its conception, since it filled a gap in the large state of California at the level of schooling with the most schools and teachers: elementary. A statewide program, it has always had a mission of networking hundreds of schools and thousands of teachers, and has succeeded in doing so. Yet issues of working with such large numbers have plagued and continue to plague the network.

Going to scale would never be a problem if we could settle for small-scale changes, but the kinds of transformational changes demanded of inquiry-based science complicate the charge. Yet what are the best strategies for reaching large numbers of people in substantial ways? We have discovered several. First and foremost, the commitment to broadly distributed leadership means that there are many people committed to reaching many more. Second, equipping those leaders with the skills and knowledge they need, as described above, makes them better able to assist others at the same time that it does two other critical things. The first critical thing is that it makes the teachers aware—sometimes painfully so—of what they do not know. This is especially the case with science content, so limited in a large proportion of elementary teachers. Time and again we have learned that introducing teachers to inquiry-based teaching and helping them look in their and others' classrooms results in a need-to-know, a hunger for understanding of the concepts and principles—the "big ideas"—of science they want their students to learn. CSIN's teacher leaders are major customers of science courses, taking advantage of all opportunities offered to deepen their knowledge of science content. In addition to making teacher leaders aware of their limited content knowledge, CSIN has built a community of experts in a variety of fields that everyone can access. Scientists and teachers from higher grade levels who serve as cadre members are eager and willing to assist teacher leaders. Few teachers alone have the ready and able resources that are part of the CSIN learning community. Going to scale means calling upon all the resources available, and CSIN has worked to make those resources accessible.

Another strategy that CSIN has used to foster change in large numbers of teachers and schools is its commitment to systemic and system-wide change. CSIN does far more than professional development. Choosing strategically to work with the school as a unit, not one-teacher-at-a-time, the commitment has been to work with all components of the school's science program, including curriculum, assessment, organizational structure, and administrative support. All are aligned, that is, are directed at the same set of learning goals for students. Curriculum materials, in particular, are very carefully selected by the school community. These materials must carry much of the responsibility for rigorous science content while teachers are building their own understandings of science. CSIN also works with the district level as much as possible to assist individuals at this level in providing the right kinds of support for schools.

With all of these strategies and perspectives, however, scale-up with quality is always an issue. How do you decide when to stop adding numbers and go deeper with those already involved? How do you ensure that teachers do not settle for grabbing the superficial features of reform rather than the deeper understanding of strong conceptually rich science teaching and learning? These are the challenges CSIN will always face in a state as large and diverse as California.

Effectiveness

A discussion of CSIN's teacher leadership component cannot conclude without considering the important issue of effectiveness. Hungry for feedback and committed to continuous improvement, we faced early on the need to identify indicators of success. How would we know that we have teacher leaders in a district? What types of evidence help to build a case that capacity has been increased through the development of teacher leaders? Certainly, there are personal transformations where people are empowered to take action. There are also other indicators. We suggest a few that we have looked for and found in CSIN teacher leaders. Teacher leaders

- are self-directed, take action, and make modifications along the way.
- take risks.
- are confident that they can problem solve.
- see opportunity when others feel dismay and discouragement.
- empower other teachers at school and district sites.
- have developed support systems at both district and building levels; support from colleagues, supervisor, community members.
- have respect for their own work and the work of their colleagues.
- feel valued and realize that their contributions are valued; value others and their contributions.

Evidence that CSIN's teacher leadership program contributes to the capacity of classrooms, schools, districts, and the state is found at each and all levels across the state. In closing, we share a vignette of how one school district built its capacity for initial and ongoing improvement of its science program, with help and support by CSIN's teacher leaders. This vignette underscores the importance of leadership that is simultaneously "top down" and "bottom-up."

The Mountainside District Story

Teacher leadership begins in two places. At the "grassroots," classroom teachers begin to see that leadership needs to come from within and are willing to take the initiative to be part of the change process. The other place teacher leadership starts is with forward thinking (innovative) administrators who recognize that building internal leadership capacity strengthens the district/school in many ways. Both places are a natural match with the CSIN philosophy: "Teachers should be empowered to become leaders within the district."

As an example, the K-12 Mountainside District found itself in need of professional development for staff members in the area of science, based upon recent statewide recommendations for changes (in this case new Science Standards (National Research Council, 1996)) and subsequent student assessment. The district had no capacity to offer such professional development at the time. So the superintendent took steps to find professional development opportunities to prepare teacher leaders.

The district held a series of community meetings during which the recommended state changes were introduced to teachers, parents, and interested community members. Through small facilitated breakout groups, participants were asked for "pluses" and "wishes:" what the district was already doing well in science (pluses) and what the community would like to see it do (wishes) to meet the new state recommended changes and improve the science program in the district. Input from these sessions served as a starting place for teams assembled from volunteers from both the education community and the community at large who were charged with developing strategies and plans for addressing each of the wishes that had been identified.

As this process of system change in the district began, the district became aware of CSIN, which promised to help them build teacher leadership to strengthen pedagogy and content understanding and improve student outcomes. The program would build internal capacity to support change by providing professional development to district teachers and giving them particular tasks to do at their schools that related to the district goals. When the district invited teachers to apply, Sarah, an innovative fifth grade teacher at Harrison School did so. The first year, she was one of few teachers from her district who participated. The second year, her hard work and success in implementing what she had learned was recognized when half of the district schools enrolled teachers in the program and Sarah moved into a leadership role, helping schools do what she had done in year one.

With Sarah's leadership and the professional development attended by the classroom teachers, they set out to design learning opportunities in science for all of the district's teachers. These lead teachers designed the science offerings for the district inservice day and were subsequently asked to provide ongoing, half-day professional development for one content strand of the district's science content matrix. The district supported the scientist to deliver the content and purchased supplies, handouts, and curriculum materials.

Today, the district's participation in what is now the K-12 Alliance has expanded from elementary teachers to include teachers at all levels. The original teacher leaders are the backbone of all staff development occurring in the Mountainside School District. Science staff development is ongoing and now includes workshops on facilitated learning, assessment, and inquiry. The leadership that began in science has transferred to other departments within the district. Language arts, mathematics, and social science committees are now guided by teacher leaders who were prepared for their roles through the K-12 Alliance. Sarah is the district curriculum coordinator and change is evident throughout district schools and in the classrooms.

Conclusions

This is just one of hundreds of stories—each unique—of the influence of teacher leaders in California schools that have been part of CSIN, and now the K-12 Alliance. Their stories are not always of glowing success, all have experienced "bumps" in their journey. But the large number of successes that have occurred rest on the combination of effort to build new knowledge and skills, support from committed administrators and communities, and belief that leadership must lie in a teaching force strongly committed to the growth of students and fellow professionals.

References

Bybee, R.W. (1993). *Reforming science education: Social perspectives and personal reflections.* New York: Teachers College Press.

Fullan, M.G. (1991) *The new meaning of educational change.* New York: Teachers College Press.

Fullan, M.G., & Hargreaves, A. (1996). *What's worth fighting for in Your school?* New York: Teachers College Press.

Harvey, T. and Drolet, B. (1994) *Building teams, building people: Expanding the fifth resource*. Lancaster, PA: Technomic Publishing Co., Inc.

Hord, S.M., Rutherford, W.L., Huling-Austin, L., & Hall, G.E. (1987). *Taking charge of change*. Alexandria, VA: Association for Supervision and Curriculum Development.

Loucks-Horsley, S., Hewson, P.W., Love, N., & Stiles, K.E. (1998). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

McClelland, D. (1970). The two faces of power. *Journal of International Affairs. 24*, No. 1, pp. 29-47.

McLaughlin, M.W. (1993). What matters most in teachers' workplace context? In J.W. Little & M.W. McLaughlin (Eds.), *Teachers' work: Individuals, colleagues, and contexts* (pp. 79-103). New York: Teachers College Press.

Mundry, S., & Loucks-Horsley, S. (April, 1999) Designing professional development for science and mathematics teachers: Decision points and dilemmas. *NISE Brief*, 3(1), 1-7. Madison, WI: National Institute for Science Education.

Myers, I.B. (1962). *The Myers-Briggs Type Indicator*. Palo Alto, CA: Consulting Psychologist Press.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Senge, P.M. (Fall, 1990). The leaders' new work: Building learning organizations. *Sloan Management Review*. Cambridge, MA: Sloan School of Management, Massachusetts Institute of Technology.

Weisglass, J. (1994). *A call for educational change leadership*. UC Santa Barbara: Center for Change in Mathematics and Science (CECIMS).

6 Building a Community for Science

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Professional development for effecting school change and school improvement is a community endeavor. While effective professional development requires all components of the local setting to be considered, the complexity of the educational system prohibits simple solutions. Building a community of leaders helps insure success in the change process. Leaders can be teachers, principals, administrators, and individuals in the community. This chapter describes an on-going 25-year professional development program for improving science education in the Anchorage School District. The development and maturation of the program are described as well as the impact on the program from various school and community members. Strategies to involve teachers, principals, central office staff, superintendents, boards of education, and related school and community members are identified.

Excellence in student achievement is a goal of the science education community (American Association for the Advancement of Science [AAAS], 1989, 1993; National Research Council [NRC], 1996; National Science Teachers Association [NSTA], 1993). Efforts to improve science education, however, create many questions. What does excellence mean? Where are the resources to insure that teachers have the necessary skills, materials, curriculum, and equipment to teach what needs to be taught? Who is really responsible for putting a program in place? What is the role of the school administrator? What is the administrator's role in empowering teacher leaders? These are all questions that seem simple yet are incredibly complex. Issues of policy, practice, and implementation of programs are intricately linked to the above questions. This chapter, which focuses on engaging an educational community in improving science education, will provide some insights that may shed light on these questions.

The complex nature of these questions prohibits simple solutions. Professional development is key in beginning to seek answers for these questions. To provide quality professional development all components of the local setting, such as cultural and organizational features, must be considered (Fullan, 1993). From this practitioner's view, there are several things which appear evident when looking at professional development. First of all, professional development often depends upon the involvement of various speakers to deliver the content. Having a dynamic speaker can provide motivation; however, if the speaker's objectives are not linked to the goals of the school or district, the opportunity to reinforce the direction that leads to improvement is lost. Careful consideration must be given to guarantee that each aspect of professional development contributes to the goals of the district or school. Second, in looking at the past, it is clear that educational change cannot be made one teacher at a time. Traditional approaches typically provide professional development for one teacher, send the teacher back to the school, and hope that changes will be made. However, without administrative support, buy-in, and continued attention, the chance of such efforts achieving success is very low. A well-developed plan for professional development involves administrative support to convey deliberate strategies for change (Loucks-Horsley, Hewson, Love, & Stiles, 1998; NRC, 1996; NSTA, 1993; Wilkes, 1994).

For professional development to ultimately impact student learning and thus achievement, it needs to be well planned, continuous, and aligned with the goals of the school and district (Loucks-Horsley, 1995). These goals must focus on students and their learning as the foundation for professional development (NRC, 1996). For long lasting school improvement, systems thinking provides a useful way to look at change. The framework for systems thinking (Senge, 1990) requires examining the whole instead of parts and views participants as responsible for shaping their own future and reality.

This shift of mind requires substantial change. This type of change is a process, not an event where leadership is the essential ingredient (Lieberman, 1988). What is leadership? Roger Bybee (1993) developed a useful characterization of what leadership includes:

- Making things happen or not happen;

- Getting others to do what they ought to do, and like it;
- Making people think things are possible that they didn't think were possible;
- Getting people to be better than they think they are or can be;
- Inspiring hope and confidence in others to accomplish purposes they think are impossible;
- Perceiving what is needed and right, and knowing how to mobilize people and resources to accomplish these goals;
- Creating options and opportunities, clarifying problems and choices, building morale and coalitions, providing a vision and possibilities of something better than currently exists; and
- Empowering and liberating people to become leaders in their own right. (p. 56)

Leaders in this change process can be teachers, principals, administrators, and members of the community. In considering the roles of administration, we must be aware that by virtue of position, there are several different layers of administration in the educational community. Assuming that systems thinking is valid, then special attention needs to be focused at each level. By their very nature and long practice of hierarchical organizations, many school districts try to make changes by mandating professional development and curriculum. This is often done without the knowledge or involvement of principals and teachers. This is counterproductive to research that indicates that mandating change is one of the least effective ways to accomplish goals (Fullan, 1993, 1997). Effective change (Hord, Rutherford, Huling-Austin, & Hall, 1987; Lieberman & Grolnick, 1997; Loucks-Horsley, 1997) must be the result of the whole system being involved in the process. Instead of defining roles for the principal, central office staff, superintendent, and the board of education, it is more productive to engage the whole community in striving for excellence in science education.

As one considers the educational community, it becomes apparent that there are many layers of influence. Universities, boards of education, municipal, state, or federal political bodies have profound effects on the education of our students even though they frequently have no direct contact with the classroom. Even at a school district level, some members of the educational community are still some distance from the classroom. However, through their direction, hiring policies, building management, and curriculum development, staff has an effect on what and how programs are delivered. Then at the individual school or building level, principals are extremely important in setting the tone. They can support or become barriers for effective teaching practices (Zinn, 1997). Ultimately, all of these members of the educational community affect the classroom teacher who has the awesome responsibility of teaching students content and processes in a way that empowers them to become life long learners.

It is well documented that the principal's role in improving instruction is critical (Hall & Hord, 1987; Parker, 1997). There are many ways principals can facilitate professional development and ultimately influence the direction of school programs. Such influence ranges from being passive and not getting in the way of teachers who are involved in improving their school programs to actively being the visionary who is the curriculum leader. In a study by Bauchner and Loucks (as cited in Anderson & Pratt, 1995), 108 principals listed the type of assistance (in descending order of frequency) they provided their teachers:

- Communication with staff
- Plan, schedule and organize
- Provide resources
- Leverage staff
- Provide support
- Attend training sessions and meetings
- Observe the program in classrooms
- Handle paperwork
- Arrange training
- Communicate with external facilitators
- Audit program
- Make recommendations. (p. 155)

These various types of support indicate the profound influence which principals can exert in impacting the curricular activities within their schools.

In order to understand the role of the community in the change process in improving science education, the following case history is offered. The case history illustrates the involvement of one school district and community in the development and implementation of an elementary science program.

Anchorage School District, 1974-Present: A Case History

Building a Community for Science

In 1974 the Anchorage School District did not have a comprehensive elementary science program, as such there were no elementary adopted texts or programs to guide the delivery of science for the district. For example, some schools had old texts that contained statements such as "someday man would walk on the moon," while other schools used Science Curriculum Improvement Study (SCIS) kits, Elementary Science Study (ESS) kits, or Science A Process Approach (SAPA). A 1973 survey focusing on the elementary school science programs in the district showed that there were 21 different "programs" which ranged from teacher-written lessons and commercial curricula to the absence of science being taught in some classrooms. Yet, some of the schools had outstanding teachers who were interested in making sure that their students had science learning experiences. For the most part, however, these teachers were few. Though some teachers and principals had been involved in National Science Foundation (NSF) institutes, there was no formal plan for these trained individuals to share what they had learned with others. What content was taught and how it was taught was left up to individual teachers with the end result often being that science was a neglected subject.

Ultimately, the district decided that this situation could not continue, which led to the hiring of the first science coordinator. When the coordinator left the following year, the author assumed the science coordinator's position. To assist in trying to define what should be taught, a classroom teacher was given a Career Development Leave (CDL) for the 1974-75 school year. The CDL teacher's responsibilities concentrated on meeting with staff, presenting lessons for students, and teaching credit courses for teachers. The road leading toward a sound science curriculum for elementary students was being built.

In 1975, the district's central office staff decided that a science program for elementary education was a priority. Influenced by text-driven approaches to teaching science, the Science Coordinator was given the task of finding a good text. She attended the 1975 National Science Teachers Association (NSTA) convention and used the opportunity to network with other science leaders. At this time (1975), elementary science was not a priority in the nation's schools; many school districts were not supporting elementary science instruction. There was, however, a notable exception--the innovative program developed by the Highline school district of Seattle (cited in *Science for All Children*, NSRC, 1997). The Highline program was kit based with units that had been either locally developed or adapted from national science programs. In addition, there was a science center where kits were refurbished before being sent to other teachers. This provided a management system that supported teachers in their teaching of hands-on science. Impressed with the innovative nature of the program, the Anchorage Science Coordinator initiated discussions with the Highline Science Coordinator in order to obtain information about their curriculum and resources.

To help with the reform effort, the Highline Science Coordinator was hired as a consultant for the Anchorage School District for the 1976-77 school year. Part of his responsibilities included meeting with teachers, selected principals, central office staff, and other key people, such as the audiovisual (AV) director for the school district to provide them with information about implementing such a program in Anchorage. During this time the consultant shared his vision for effecting change in science instruction.

A pivotal development in the Anchorage school district came in the formation of a principals' support group comprised of principals who had expressed an interest in science education. Subsequently, the elementary director, the CDL teacher, and the Science Coordinator invited seven principals to serve as an advisory committee. The principals soon realized that elementary science should be hands-on and that teachers need support through the availability and maintenance of materials. Luncheon meetings provided a forum for conversations among these professionals as they grappled with solving problems and engaged in heated discussions. It became evident that conducting these meetings during lunch and providing food contributed to creating enthusiasm and building a community.

At the same time that the principals were having their monthly meetings, teachers and a principal representative were involved in an Elementary Science Curriculum Committee charged with developing a scope and sequence for elementary science. Their meetings were spent in essentially the same way as the principals--discussing what should be taught and how it should be taught. The meetings contributed to growth in understanding of what constitutes effective science instruction. Consequently, additional support was gained for the development and maintenance of a comprehensive science program.

Other members of the community were also essential players in the development of Anchorage's elementary science program. Early in the effort, a group of community members formed an organization named, "The CommittEE," (where the EE represented Environmental Education). The CommittEE was interested in working with the district and in providing support for a quality science and environmental education program. For example, The CommittEE developed an Outdoor Week that provided each sixth grade class and teacher with the opportunity to spend a day at the Bureau of Land Management site where they experienced hands-on interactions with professionals from many different agencies and organizations. For example, students learned about plant identification, Alaskan animal behavior, orienteering, and other science-related topics. Additionally, The CommittEE was instrumental in providing important media attention for the science program. This media attention raised the level of community awareness about the importance of science to children and provided education about the role of the larger educational community in shaping the science program.

Concurrent with the activities of the principals, curriculum committee, and The CommittEE, professional development with university credit was offered by the district. The staff development department helped by providing presenters for inservice and facilitating one-credit university courses which included cutting edge science educators such as Harold Pratt, Harry Wong, Virginia Johnson, the late Mary Budd Rowe, as well as local science educators.

In January 1977, the AV director offered to offset the costs of establishing a science center by providing some funding. With $19,000.00 budgeted for materials, preparation began for establishing this central component in the District's plan to improve science education. During the next year, the Science Coordinator adapted and revised the Highline school district's elementary science curriculum, ordered materials, located a home for the science center, collaborated with principals to set up a pilot program, teamed with the Elementary Director to convert the CDL teacher into a teacher expert, and reached out to involve the various stakeholders in order to promote a feeling of ownership.

The principals in the advisory group felt so strongly about the benefits of the newly developed science program that each of the seven principals offered one-seventh of a Full Teacher Equivalent (FTE) in order to fund a teacher expert position. This position was different from the CDL position in that the teacher expert was to work exclusively with the seven schools and not the whole district. The teacher expert worked with the Science Coordinator and met with teachers and principals at each of the seven schools to "sell" the program. To be a part of the science center program, each school was required to donate their science equipment and materials to the science center to be used in the kits. Each school also committed to scheduling visits by the teacher expert who modeled lessons in the classrooms. The audiovisual department, through a federal program, funded a science center clerk and provided space for establishing the center. In January 1978, the first kit was delivered through the AV delivery system. The program was like a toddler--beginning to walk.

The principals involved in the program shared their excitement about the program with other principals. It was shortly after the first kit was sent out that the Science Coordinator began receiving calls from other principals interested in becoming a part of the science center program. These schools were recognizing some of the advantages of the new program--not having to order textbooks, not having to provide petty cash for those teachers who wanted to do their own activities, not having to find a place for or to manage science materials at the school, and most importantly, having a rich science program to teach in their classrooms. The following year there were 11 schools which opted to participate in the program, each offering a part of a FTE, resulting in allocations for an additional teacher expert. By 1979, twenty-five schools were participating and two more teacher experts were hired. The teacher experts continued to provide demonstration lessons, to be available to work with individual teachers, to write and revise curriculum, and to teach one-credit university courses.

Within five years, all the district's elementary schools were participating in the science center program. This remarkable growth and the far-reaching community support led to actions that institutionalized the program. The board of education, in a policy decision, officially sanctioned the science center program and mandated the teaching of four units per year in each elementary classroom. The district then assumed the responsibility for funding four teacher experts, for housing the Science Materials Resource Center, for funding four clerks who maintained the kits, and for the delivery system including a truck and full-time driver. The science center delivered the kits to the teachers, picked them up on a specified date, refurbished the kits, and then sent them on to other teachers.

Although the program became an official part of the district's curriculum, it was critical to maintain the involvement of the educational community which had labored hard to bring about such change. Due to funding limitations, there were times when the program was being developed that the help necessary to put the science kits together was unavailable. An example of continued community support came in the form of The CommittEE who stepped in and helped assemble the kits. Members would come to the science center after work and donate two to three hours of their time. It was always a new experience, because the activities were often completely out of the ordinary such as plucking feathers from dead frozen ducks, assembling a kit that had twigs that had been "moose browsed," or counting out and shellacking moose droppings. The sense of community was exemplified by the willingness of the participants to provide meals during these work sessions. As a result of the superb efforts of the science center in sustaining the program, the center obtained state and national recognition, which resulted in three of the teacher experts as well as the Science Coordinator teaming with the National Science Resources Center in the development of its national program.

The development of the elementary science program, the involvement of the central office, and the change process for the teachers were not easy or simple. The science center went through scrutiny each year as budgets were approved. One year, all the teacher experts were eliminated and the program had to run with only the clerks, a driver, and the Science Coordinator. The program survived, and the next year funds were found to fill the position of one teacher expert.

These transitions and the maturation of the program provide many valuable lessons. One factor that became apparent was that the teacher experts giving demonstration lessons was not the best way to help classroom teachers become more comfortable with teaching hands-on science. In too many instances the classroom teachers perceived the teacher experts' demonstration as the science program. This realization was a primary factor in the reconsideration of professional development for teachers. Until 1993, most of the professional development for elementary teachers was voluntary which meant that teachers who were reluctant and resistant to teaching science were not necessarily being reached with quality professional development. Principals also began to vocalize the need for all teachers to have more professional development that led to meetings with the principals and the Science Coordinator. From these meetings, it was evident that the first challenge was to provide a systematic professional development program which would directly impact all elementary teachers.

Consequently, the district wrote and submitted a proposal whose primary purpose was that of providing a systematic professional development program for the district's 1500 elementary teachers. In 1994 the proposal was funded by the National Science Foundation (NSF # ESI 9454411). The principle investigator for the project and the teacher experts were hired to provide the professional development component. The NSF expectation was for all elementary teachers in the district to participate in 100 hours of training. It was also expected that principals would be involved in the professional development program. While principals did not participate in all professional development activities, it is safe to say that each principal participated at least one third of the time.

The implementation of a quality science program in the Anchorage District has been successful to a great extent due to the support and ownership of the elementary principals. Research substantiates that skillful principal are key in improving science education (Fullan, 1993; Lieberman & Grolnick, 1997; Loucks-Horsley, 1997). Today, the program is intact with all the Anchorage School District's 60 elementary schools involved in the delivery of a quality science program. In retrospect, the benefits of the early involvement of teachers, principals, the Science Coordinator, and community members in a new program cannot be overemphasized as they are critical when striving for district-wide sustainable change.

Lessons Learned from the Anchorage Experience

The strategies used in building a community for science in the Anchorage School District included the involvement of teachers, principals, central office staff, superintendents, boards of education, and community members. As the program matured, it became evident that the success of the program hinged on the involvement of all members of the educational community. Several valuable lessons emerged from the Anchorage experience, providing strategies for enhancing community support in building and implementing new programs.

First of all, principals can provide support for teachers in a variety of ways. This support empowers teachers engaged in educational change. In the Anchorage district principals demonstrated support by providing time for study groups, involving teachers in decision making, and providing professional growth opportunities for teachers.

Study groups are a way of providing the time and incentive for teachers to explore ideas, problems, and innovations. The outcome of these meetings can drive a program. In order for these study groups to be successful, teachers must be comfortable in taking risks and sharing their problems, successes, and ideas.

Teachers can be involved in decision making by serving on committees allocating budget and resource utilization. Examining school goals and the resources that are available to accomplish them helps both the principal and teachers. Holding grant workshops that provide a focus on writing and submitting proposals allows teachers and principals to actively think about what they feel is important. Clarifying goals for a proposal involves teachers and principals in decision making. Additionally, budget development is useful in providing a mechanism for goal clarification. Teachers can take the lead in planning how professional development will happen at their school, by examining goals and developing a program to support the active involvement of all teachers, thus enhancing teacher ownership of the program.

An excellent way to empower teachers is for principals to encourage teachers to apply for professional experiences in which they have an interest. For example, one teacher asked for and received some limited funds to study dinosaurs in Montana. She returned to her school and shared her ideas, materials, and equipment; consequently, the entire school benefited greatly from her summer of study.

Further, it is vital to involve superintendents, boards of education, and central office staff in the entire process of curricular change. When working with these stakeholders, it is advantageous to consider the size of districts since this can influence the nature of the selected activities. In general, larger districts have developed more procedures to follow than smaller districts. Regardless of the size of the district, it is important to understand the structure and to work in a cooperative manner. Superintendents are the designated leaders of school districts and need to be kept aware of the newest trends, developments, and programs. Since professional development decisions often reflect the direction and goals of the superintendent, it behooves the science education community to keep awareness levels of science education highly visible to the superintendent. Working with the superintendent, it is the primary task of the board of education to allocate resources to provide the best educational system for students. Such decisions create multiple demands on boards who may or may not have an understanding of effective science education. Strategies to increase the awareness of the importance of science education are critical when working with superintendents, and local and state boards. However, a caution must be noted since some districts may have strict rules about contacting board of education members. By all means, work within the system. Leaders in science education must initiate action towards better communication through the proper channels.

Some specific strategies for working with the superintendent, boards of education, and central office staff include the following:

Form partnerships. Work together on projects, share information about what you are doing, and invite them to your meetings and celebrations.

Prepare completely for any meeting. Clearly outline the goals, objectives, timeline, cost, and outcomes of requests or proposals.

Seek professional opportunities that could involve local educational leaders. Provide information about science conventions and invite central office staff, superintendents, or members of the board of education to attend local and state conferences and conventions or ask individuals to serve as speakers for a session. Many of the NSF projects require that the superintendent be involved; the National Science Resources Center (1997) has conducted leadership conferences for many years and expects the superintendent or assistant superintendent to be a part of the team.

Invite these leaders to functions that celebrate students' and teachers' work in science. An invitation to a science fair highlights the importance of the event. Provide science journals for them to read in order to increase their familiarity with science programs and materials.

In addition to these lessons, there are some general words of encouragement, which are important to keep in mind. Though the advice sounds cliché, it is easy to become frustrated when taking on such a monumental endeavor. Start small. It is easier to build up a good program step by step than to try to make wholesale changes.

Success builds on success. Celebrate successes. Being on a winning team is an important aspect of building a community. Do not be discouraged when setbacks occur. Learn from the challenges and failures then revise the plans.

Conclusion

The collaborative experiences of teachers, principals, the Science Coordinator, and the community in improving science education in the Anchorage School District provide insights for professional development. Effective professional development builds a community of learners who can support and facilitate change. Resources, however, must be available for the professional development component. This does not mean that we can not accomplish our goal if we do not have funds, but it might require reassigning our resources. A good example is the donation of volunteer time from The CommittEE. Further, take advantage of the resources that are available. An example is that the Anchorage school district science center started in the AV hallway. When it was apparent that this program had potential for improving elementary science education, space was found to expand the actual facilities for the equipment, materials, kits, and clerical staff. In addition, examine approaches that enhance the leadership potential of all teachers. Even when there are teacher experts and resource teachers, they should support not replace the role of the classroom teacher in teaching science. In general, careful analysis needs to be done in order to best utilize human resources.

Systemic change is possible in education, however, change does not happen overnight. It is a complex process requiring the involvement of the whole community if change is to be sustained. To actually make differences that improve science education, all players must be involved in building the community. Another key factor in systemic change is the role of professional development with the goal of providing a quality science education for all students. A well-designed plan of professional development, such as the one that has been used for 25 years in Anchorage, is essential if a school system is to assist all students in becoming scientifically literate.

References

American Association for the Advancement of Science (AAAS). (1989). *Science for all Americans*. New York: Oxford University Press.

AAAS. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Anderson, R., & Pratt, H. (1995). *Local leadership for science education reform.* Dubuque, IA: Kendall/Hunt Publishing Company.

Bybee, R. (1993). *Reforming science education: Social perspectives and personal reflections.* New York: Teachers College Press.

Fullan, M. (1993). *Change forces. Probing the depths of educational reform.* Bristol, PA: Falmer Press.

Fullan, M. (1997). Emotion and hope: Constructive concepts for complex times. In A. Hargreaves (Ed.), *Rethinking educational change with heart and mind, Association for Supervision and Curriculum Development (ASCD) 1997 yearbook* (pp. 216-233). Alexandria, VA: Author.

Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process.* Albany, NY: State University of NY Press.

Hord, S. M., Rutherford, W. L., Huling-Austin, L., & Hall, G. E. (1987). *Taking charge of change.* Alexandria, VA: ASCD.

Lieberman, A. (1988). Expanding the leadership team. *Educational Leadership, 45* (5), 4-8.

Lieberman, A., & Grolnick, M. (1997). Networks, reform, and the professional development of teachers. In A. Hargreaves (Ed.), *Rethinking educational change with heart and mind, 1997 ASCD yearbook* (pp. 134-149). Alexandria, VA: ASCD.

Loucks-Horsley, S. (1995). Professional development and the learner centered school. *Theory Into Practice, 34* (4), 265-271.

Loucks-Horsley, S. (1997). Teacher change, staff development, and systemic change: Reflections from the eye of a paradigm shift. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement projects in K-6 mathematics* (pp. 134-149). Lanham, MD: University Press of America.

Loucks-Horsely, S., Hewson, P. W., Love, N., & Stiles, K. E. (1998). *Designing professional development for teachers of science and mathematics.* Thousands Oaks, CA: Corwin Press.

National Research Council (NRC). (1996). *The national science education standards.* Washington, DC: National Academy Press.

National Science Resources Center (NSRC). (1997). *Science for all children: A guide for improving elementary science education in your school district.* Washington, DC: National Academy Press.

National Science Teachers Association (NSTA). (1993). *A strategy for change in elementary school science.* Proceedings of a conference. Arlington, VA: Author.

Parker, R. E. (1997). Comprehensive school and district restructuring of mathematics: Principles and caveats. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement projects in K-6 mathematics* (pp. 238-246). Lanham, MD: University Press of America.

Senge, P. (1990). *The fifth discipline: The act and practice of the learning organization.* New York: Doubleday.

Wilkes, D. (1994). *Schools for the 21st century: New roles for teachers and principals.* Greensboro, NC: SouthEastern Regional Vision for Education.

Zinn, L. F. (1997, March). *Supports and barriers to teacher leadership: Reports of teacher leaders.* Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

7

Developing and Maintaining Implementation of a Teaching-for-Thinking Program

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This chapter describes an inservice Professional Development (PD) program for introducing a *cognitive acceleration* course designed to enhance students' higher order thinking capabilities. Teaching for thinking requires a specialized set of understandings and techniques, and the standard PD program described here lasts for two years and includes both center-based days and in-school coaching. We explore the principles upon which this standard program is based, and a variety of alternative modes of delivery using teacher leaders. While maintaining the same basic principles of the program, modes of delivery are adapted to suit particular contexts.

This chapter describes a process of developing teachers' ability to stimulate their students' cognitive processing capability, and addresses problems inherent in maintaining the use of this ability. Stimulating children to raise their levels of cognitive functioning is a subtle, complex process that could never be achieved simply by following some recipe from a cookbook style teachers' guide. The reason there can be no such thing as a 'teacher-proof curriculum' is that the process of teaching is an essentially social enterprise involving myriad types of interaction between teachers and pupils. For teaching to be effective, each teacher has to find her or his own way of working with the great variety of personalities and intelligences which they meet every day. Teaching can no more be reduced to a programmed set of procedures than human activity can be mimicked by robots (Pinker, 1997).

If these principles are true for teaching in general, they are even more important when applied to teaching for the development of reasoning. We must consider what teachers of thinking need to be able to do, what normal training and experience have prepared them for, and how the gap between the two might be closed. Here we will focus on the inservice education of practicing teachers at the level of individual teacher, subject department within a school, whole school, and Local Education Authority. That is, we will consider both the individual teacher and the context that supports that teacher in making changes. The role of teacher leaders (whom we have called *Tutors*) in this process will be described.

Cognitive Acceleration: Successful programs

Cognitive Acceleration through Science Education (CASE) and Cognitive Acceleration through Mathematics Education (CAME) are intervention programs designed for grades 6 and 7 which have the specific purpose of developing students' higher order thinking capabilities. Their methods are rooted in Piagetian ideas of cognitive conflict and equilibration (Gruber & Vonèche, 1977), and in Vygotskyan ideas of social construction and metacognitive reflection on the development of one's own thinking (Vygotsky, 1962; Vygotsky, 1978). Activities are described in a set of pupil worksheets and teachers' lesson notes (Adey, 1993; Adey, Shayer & Yates, 1992; Adey, Shayer & Yates, 1995; Adhami, Johnson & Shayer, 1998). Schools are advised to use one of these special activities every two weeks in the place of a regular science or mathematics lesson, over a two-year period. CASE was originally developed and evaluated during 1981-87, and since then use of the program has continued to grow and evidence for its long-term effectiveness continues to accumulate. Results have been extensively reported elsewhere (Adey & Shayer, 1993; Adey & Shayer, 1994; Shayer, 1996) and here we only summarize the effects. In the original study, students in classes using CASE were shown, in comparison with matched control classes, to:

- Make significantly greater gains in cognitive development over the two years of the intervention.
- Attain higher levels in subject achievement tests one year after the end of the intervention.
- Gain significantly higher grades in nationally set examinations taken three years after the end of the intervention, not only in science (the context in which the activities had been set) but also in mathematics and English.

The CAME program is more recent, having been developed during 1993-94, but early results show that it appears to produce similar far-transfer effects on students' academic achievement (Adhami, Johnson & Shayer, 1997).

Subsequently, effects of the Cognitive Acceleration (CA) programs have been evaluated using an 'added value' methodology. The mean grades achieved in national tests of science, mathematics, and English by schools using CA are shown to be significantly higher than those of non-CA schools after school-entry mean cognitive levels are partialled out. We have argued from this long-term, far-transfer effect that the CA programs have a permanent effect on students' general intellectual processing capability.

But this is less than half of the story. CA is not a 'magic bullet'. It is not sufficient for schools simply to buy the printed materials and have their teachers follow the activities as written to produce the kind of effects that have been repeatedly demonstrated. No teachers' guide, however comprehensive, can ever convey the richness of a classroom practice that is required to raise permanently students' general levels of thinking. A substantial process of inservice teacher education is required. To understand this, we must look at the demands made on an effective teacher of thinking.

Needs of teaching for thinking

Some idea of the problem can be gained by contrasting the pedagogy required for good content instruction with that required for developing students' cognitive capability. In the former case, the content of a lesson is readily describable (e.g., "to establish a relationship between the volume of a gas and its pressure"). The content is also generally quite familiar to the teacher, who has been trained in the subject matter she or he is teaching. Furthermore, success is relatively easy to check—a quick end-of-lesson quiz will reveal the extent of students' understanding of the content. In contrast, the cognitive processes that a teacher of thinking is targeting are hidden, there is much uncertainty in their slow development, and there can be no immediate feedback to the teacher about success at the end of one or two lessons. The process is much slower and more subtle than this.

The development of critical thinking, or higher level reasoning, in children requires by definition that children be given an opportunity to exercise their own minds, to engage in critical appraisal, to risk opinions in a sympathetic atmosphere and then have the opinions challenged in a rational but respectful manner. This means the creation in the classroom of a very special sort of atmosphere which is intellectually rigorous but at the same time friendly and safe in the sense that all children should feel confident in taking cognitive risks. To create such an atmosphere, the teacher needs to have:

- Clear objectives in terms of the type of reasoning being developed in a particular thinking lesson.
- Familiarity with the materials of a particular thinking skill program and with its underlying theory or philosophy.
- A close understanding of the range of reasoning and arguments displayed by his or her pupils, if not of the particular levels of argument employed by each individual pupil.
- The ability to 'read' an individual's response or the progress of a whole lesson in terms of the levels of understanding exhibited and the challenge provided and to offer the right type and level of stimulus in the context of the cognitive objectives of the program.
- Mastery of a range of techniques such as leading questioning, suspension of judgement, managing student peer-review of each other's arguments, setting challenges appropriate to particular children, and the ability to interpret children's utterances in terms of the type of thinking they are using.

The 'needs list' may be seen as something of a specialization in the requirements placed on any teacher, rather than a radically different type of teaching. It is, or at least should be, part of every good teachers' repertoire to be clear about objectives, familiar with teaching materials, sensitive to children's needs, and in command of questioning and other techniques. But for the development of reasoning in children, each of these requirements is raised to a higher degree, or applied to rather particular methods and materials that are quite different from the normal content-oriented curriculum.

We suggest that underlying the skills of a successful teacher for thinking lies a fundamental confidence in her or his own subject knowledge and ability to manage a class of young adolescents. Such confidence is understandably rare in student teachers, and thus it may generally be unrealistic to expect to develop effective teachers of thinking in pre-service courses. We can however sow the seeds of curiosity and indicate what possibilities lie ahead for those interested. It takes a few years of practice for classroom management skills and pedagogical content knowledge to become well established. Only then is the time is ripe for the further professional development of teachers to upgrade their understandings and skills to the level required for the effective promotion of higher level thinking in their students.

An inservice course for CA teachers

Principles

In designing an inservice professional development program to introduce CA to teachers, we have drawn on several elements, including: research into effective staff development; research into cognitive development; our own extensive experience of running such courses; the feedback we have had from participants; and the measured effects of the courses on student cognitive gains. Here are some of the principles that have emerged from such research and experience:

- The required change in pedagogy is likely to be slow. The middle school CA program itself was designed to run over a two-year period in the belief that it would take at least that long to produce significant cognitive acceleration effects. This was based on the experience of Instrumental Enrichment (Feuerstein, Rand, Hoffman & Miller, 1980) and was borne out by a sub-trial of an intensive one-year version of the program that failed to produce the same effects as the 'regular' two-year version. A professional development course is designed to run in step with the intervention. Thus teachers are introduced to the underlying theory and the first few activities, they try them out, and then return for further inservice to share experiences and reflect on their own development.
- Change cannot be achieved through individual teachers working alone. In the initial trial of CASE, we worked with just one teacher in each school. They were enthusiastic and able, but after the trial none continued to use the activities. This was partly due to external forces (at this time a National Curriculum was introduced to schools in England) but was certainly also influenced by the difficulty these individuals encountered in trying to maintain a different type of pedagogy from that of colleagues in the

same school. We now insist on working with whole science or mathematics departments, and build into the inservice course activities which ensure that teachers in a school share experiences, with the aim of building up a *community of practice* within the school.

- Real change is only brought about when the inservice course includes a coaching element. During the course Tutors must get into the school, into the participants' own classrooms, and with a combination of observation-and-feedback, team-teaching, and occasional demonstrations show that the techniques do work in anyone's class. Joyce and Showers (1995) have shown conclusively from a meta-analysis of research on effective professional development that courses which are only center-based and not school-based rarely bring about any real change in teaching practice. It is too easy for teachers to dismiss skills they have learned in the context of a university or professional development center as "All very nice, but it wouldn't work with my kids." Even when they have a real will to try out new techniques, the reality of school frequently overwhelms them.
- Changing one's teaching style can be a painful process, and the more experienced and successful a teacher is, the more uncomfortable they are likely to find the change process. We always warn teachers that even those who are well-respected by their students and peers, who achieve high academic levels for their students, and who have mastered to a high degree the skills of content instruction, will find themselves at times feeling like newly qualified teachers. Recognizing the pain is the first step in overcoming it, and knowing that colleagues are having similar experiences makes for a departmental atmosphere of sympathy.
- Change in pedagogy is not simply a matter of perfecting new teaching techniques. It requires, in addition, an understanding of some of the underlying theoretical principles of the CA program, and also some capability for managing the change amongst colleagues as well as personally. In the early stage of our CA PD course we introduce the theoretical constructs of cognitive conflict, metacognition, and the schema of formal operations. Over the two-year period of the program we continually refer to these 'big ideas' and relate them to practice, especially in the center-based reporting back sessions and in the in-class coaching.

Towards the end of the first year of the course, we introduce some managerial ideas such as needs analysis and action planning to the key players in a department, aiming to provide them with assistance in the management of change process (Fullan & Stiegelbauer, 1991).

- Finally, we recognize the reality that commitment often follows practice (Shulman, 1986; Stoll, 1992). One cannot expect teachers to become committed to a new approach to their craft until they have thoroughly tried it. It is often necessary to ask them to make a leap of faith into the new pedagogy, encouraging them to make this leap with the statistical evidence of the effects of CA on student academic achievement, and the stories of others who have gone before them. As one might expect, not every member of every department we have worked with over the last ten years has been prepared to make the leap!

Practice

Over the two years of the CA PD programs, there are at least seven days when teachers attend an inservice center, and a further five or six half-days when Tutors work with the teachers in their schools. A typical complete program is summarized in Table 1.

Teacher feedback plays an important role in the whole PD program. We sometimes talk as if the only purpose of teacher feedback is to inform program designers about what works and what does not so they can modify their programs. This certainly is one function of teacher feedback, and one that might be seen as a new ownership right of teachers as they implement a curriculum method. But of more direct relevance to teacher development is the opportunity that giving feedback provides for the teachers' own reflections on what they have experienced. Here we have the metacognitive processes at work. The process of sharing experiences with others involves putting into words both accounts of what has occurred during lessons, for good or ill, and an evaluation of those events in light of the overall aims of the cognitive intervention program. Participants at inservice workshops often report that the most valuable experience has been the opportunity to talk with other teachers. This is partly because teachers are somewhat isolated within their own classrooms and schools are isolated from each other. But sharing is also valuable because the process of debriefing a series of lessons in a professional environment

Table 1
A Typical Two Year CA Professional Development Program

Year / Month	Center-based	School-based	Purpose / Activities
1 / July		1/2 day	Meet with school principal Meet with all science or mathematics teachers, outline principles, timetable, and commitment required. Provide plenty of opportunity for questions and for all to raise concerns.
1 / July	2 days		Introduction to underlying theory. Go through first 6 activities, the testing program, and administration of the pre-test. Develop individual school plans.
1 / Sept.-Dec.		1/2 day	Tutors coach and/or team-teach with teachers who are starting implementation in their own classes.
1 / Jan.	2 days		Schools give feedback on progress so far. Receive more in-depth information on theory, experience next few activities, and discuss issues around the management of change in the schools.
1 / Jan.-June		1/2 day	Tutors coach and/or team-teach with teachers in their own classes. May hold session with whole department.
1/ May	1 (+2) days		Residential convention: 1 day for CA PD participants only. Here they share experiences, work on bridging, write own "Thinking" type materials. Two extra days can be attended by participants who are new to CA or 'old hands'.
2 / Oct.	1 day		Experience more activities. Update school plans, and consider further management issues.
2 / Oct. - May		2 x 1/2 days	Tutors coach and/or team-teach with teachers in their own classes. May hold session with whole department.
2 / June	1 day		Post-test and collect data. Forward plans. Network for continuing support.

gives one a safe opportunity to re-live experiences and bring to consciousness, perhaps for the first time, the extent to which the intended structure of the lesson was managed. The rediscovery of Dewey's (1933) recognition of the role of teacher reflection (Zeichner & Tabachnick, 1991) is encouraging to the enterprise of those involved with change in classroom practice.

While we insist on working with whole departments, it is not practical for every science or mathematics teacher in a school to come to the "center days" that are held during normal school time. We do, however, insist that at least two teachers from each department attend, giving them a chance to interact with each other and consider how the messages of the inservice days may be translated into the context of their school. Typically one participant from a school will be the *CA coordinator* in the school, and participation may rotate among others in the group, with a different person coming to each occasion. This provides a balance between continuity and exposure to the PD program by as many teachers in a department as possible. In addition to our own input in the schools, CA coordinators are encouraged to develop implementation plans that include in-school sessions that they facilitate. We use part of our school visit time to support the coordinator in his or her in-school sessions, and provide every school with a comprehensive pack of PD materials (Adey, 1993).

To summarize the features of CA PD, it involves:

- Targeting a whole department in a school over a two-year period.
- Working intensively with one or two teachers, but offering all members of the department support.
- Dealing with the practicalities of the materials and activities, the underlying theory, and the management of change.

Even though this is a relatively expensive program for a school to commit to, we always have more applicants than we can accept. This is a reflection of the perceived value of CA.

Some evaluation

As part of a continuing process of evaluation of the effects of CA PD and the factors which influence change in schools (Adey, 1997; Adey, Dillon & Simon, 1995), we have looked at the longevity of effects of one of the PD courses. During the academic year 1998-99, we visited twelve schools that had been enrolled in the 1994-96 CASE program to see what effects were still discernible in the schools. Three undergraduate psychology students conducted interviews with key teachers, gave questionnaires to students who had been in grades 6 or 7 at the time, and collected data on cognitive gains. In brief, in five of the schools the CASE program was being maintained by the science department with regular in-school inservice opportunities for new teachers, and support meetings. These schools reported some difficulty in maintaining the impetus, but in every case one or two key individuals who had participated in the CASE PD program had made it their responsibility to keep active the CA methods of teaching. In two schools, some teachers were continuing to use CASE and enjoying it, but the approach was not integral to departmental expectations. In the remaining five schools, there was little or no CASE teaching continuing. A study of the reasons for these 'failures' is illuminating. In two cases, the innovation had never really taken root from the start. In the remaining three cases, the initial implementation had been quite thorough, but the impetus for the innovation remained in the hands of just one or two key people. When supportive individuals left a school, often to promotion in another school where their CASE expertise was valued, their former departments did not maintain the methods.

Although the standards we set for longevity were high, this is not a particularly happy story. It does suggest, though, some essential factors for successfully cultivating permanent change in practice. Pedagogic practice is embedded within the professional behavior of people, but it also requires the right sort of managerial environment. The school principal or another senior administrator has to be convinced of the value of an innovation to provide the funding and time needed, and individual teachers have to commit themselves to the sort of uncomfortable learning described earlier. When one or two trained and committed people move from one school to another, the school that funded the training may be left without a critical mass of teachers with the appropriate attitude and expertise. Additionally, the teachers who move may find it difficult to put their newly developed skills into practice in new departments that have had no exposure to the specialist coaching.

Another lesson learned is that the transfer of an innovative practice from one teacher to another within a department is a far more difficult process than we had imagined. When initially committing to the project, principals seemed to believe (and we probably did not do enough to disabuse them of this belief) that the seven inservice days plus five half-day visits to the schools were sufficient to change the pedagogic culture of a school. It is not. To the basic program must be added plenty of time for the teachers within a department to share practices, observe one another, think through the underlying theory, face resistance, and generally achieve a deep sense of ownership of the new methods.

Consequently, we have modified our basic program for schools in the light of this small evaluation study, but more significantly, we have shifted the emphasis of our work from individual schools towards wider systemic change, which will be described in the next section.

CA Tutors

We have described the standard CA PD course in some detail, as it is necessary to see what is required of Tutors who run such courses. This section will elaborate on the various types of teacher leader systems we have developed. From the start of our PD programs in 1991 we have offered, in parallel with our work with individual schools, courses for CA Tutors. These are people who, in addition to developing the skills and understanding of CA teachers, are prepared to run CA PD courses themselves for individual schools or clusters of schools. These individuals typically are either university faculty members or Local Education Authority (LEA*) advisory teachers or inspectors. They may also be freelance consultants or regular teachers. They participate in the same course as CA teachers, and they also are required to teach a large proportion of the CA activities. For those who have been out of the classroom for some time, this is often a salutary experience. It is considered essential for any CA Tutor to have first hand experience with the activities and the special pedagogic techniques of the program. In addition, they accompany the regular Tutors on their coaching visits to schools, initially observing the coaching process, then sharing in it, and finally conducting coaching visits themselves, while being observed by an experienced Tutor.

Some Models of Tutor Implementation

In this section, we provide some thumbnail sketches to exemplify the way that different CA Tutors have developed constituencies of CA training while retaining contact with, and drawing on the expertise of the CA originators.

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* In the United Kingdom, schools are administered directly by a Local Education Authority. A small suburban LEA may have as few as six secondary schools and twenty primary schools, while a large urban or county LEA could have sixty secondary and hundreds of primary schools.

A University-based model

Two lecturers in the School of Education at Keele University participated in the full CA Tutors' course at Chester, and they worked with many schools in the Northwest. Now they provide CA courses for a wide variety of schools in the region of their own university. They maintain contact with the core team through the annual CA convention, and share participation in other CA events, such as invitations to present at the Scottish National CA Convention, or CASE days run by the University of Birmingham.

An LEA-Based Model (1)

Birmingham is Britain's second largest city. Readjusting to a modern economy from a long tradition of heavy industry (steel and car building), Birmingham typifies many large cities in the post-industrial era, with poverty and urban depredation. There is also significant renewal in the city and a popular culture that now owes as much to the Indian sub-continent and to Afro-Caribbean influences as it does to the traditional white working class of the Midlands.

In 1997, the Chief Education Officer of Birmingham made a commitment to introduce CA methods into all of the city's secondary schools. Two individuals were appointed as trainee CA Tutors, and an initial set of 17 schools volunteered for the first training cohort. Tutors from King's College London (the original source of CA) ran the initial training course for these schools at a Teachers' Professional Center in Birmingham, assisted by the trainee Tutors. Over a period of three years, new cohorts of schools joined the effort, the King's Tutors gradually withdrew their input, and the two Birmingham Tutors accepted more and more responsibility. By September 1998 the Birmingham Tutors were successfully training CA cohorts on their own.

An LEA-Based Model (2)

Sunderland, in the North East of England, is a smaller educational authority than Birmingham, but shares much the same post-industrial trauma and renewal. In 1991, the Sunderland LEA identified a science teacher as having the potential to become a CASE Tutor and sent her to the first CA Tutor program offered at King's College in London. She began working with a group of five Sunderland schools, including her own from which she was given part-time release. Within three years, these schools started to show the sort of long-term effects which had been seen in schools working directly on the CA PD course. In due course, the new CASE Tutor became a university lecturer and moved out of the Education Authority position. But one of the teachers she had worked with (the second author of this chapter), took over the tutoring role while also introducing the CAME project in 1997. The Authority has further expanded the training from 1999 to 2002 aiming to offer the CAME and CASE training as part of its standard provision for all secondary schools.

The training model drew heavily from the basic features of the King's model described earlier, but was tailored to suit the particular context of the Sunderland schools. The distinguishing feature of this model is that the LEA made a deep commitment to introducing CA to its schools, and expressed this commitment by providing funds for a full time Tutor. This allowed more time to be devoted to each school than could normally be provided if the schools had to fund the whole PD themselves. Key aspects of the Sunderland model are summarized below.

- The intervention is viewed as experiential and school specific, with the Tutor being able to adapt to individual institutional needs over the two years of major support. The role of the Tutor is critical. The Tutor is viewed as a supportive and experienced friend of the teachers because he was recently a teacher himself and also because his role is not associated with the formal Authority Advisory Service. The Tutor has a number of responsibilities: observing and coaching, facilitating departmental meetings, presenting training sessions for teachers and facilitating a local conference.
- There is a wide range of Tutor support available for each department and teacher involved. This support includes 14 half-day meetings over a period of seven terms* and includes a local CAME/CASE conference each autumn. In three of these meetings, the Tutor presents a CA lesson that teachers observe

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* The British academic year is broken into three terms: winter (September-Christmas); spring (New Year-Easter), and summer (Easter-July). The seven terms referred to here start with the summer term at the end of one year, and continue through the end of the summer term two years later.

and critique. Each teacher also receives at least 14 lesson visits from the Tutor over the two years. Teachers have a number of experiences: observing and coaching, demonstration teaching, team-teaching, chairing meetings, analyzing videos, and assisting in presenting training sessions. The use of coaching leads to the development of a common set of standards among the teacher group.

- There is a strong focus on the use of video materials. Teachers discuss videos of the Tutor delivering CA lessons, and the Tutor and teacher critically review videos of the teachers' lessons. Later, as the teachers' confidence grows, they begin to share their videos with other teachers. The use of video and written notes as part of the feedback process, together with the theoretical input from the training sessions, promotes reflection and evaluation and enables the teachers to move from an intuitive feel for the activities to a strong internalization of the theory.

This general process can be illustrated with some specific examples of schools that have participated in the program. The brief sketches are intended to give a flavor of the variety of activities that take place in different schools and the flexibility that is possible within the Tutor-led LEA-based model.

School 1.

This school is known for achieving high levels of academic success for its students. The departmental interest in CASE arose from dissatisfaction with the senior students' performance in a university entrance course due to poor reasoning and communication skills. All fifteen science teachers decided to participate in in-school sessions in which they observed a demonstration CA lesson. They also agreed to the Tutor observing half the department's teachers. Time was given to both individual and departmental feedback on lesson practice.

School 2.

School 2 was identified as having problems with poor examination results, so the senior management decided that the school should adopt CAME. The math department consisted of four committed teachers who had all been teaching for some twenty years. Good communication was a strong feature of this department. After just one term of CAME they reported finding the materials and the support of the tutor refreshing. The department thrived with the opportunity to observe themselves on video and also to observe the Tutor. Some teachers even used their video materials as part of their higher degree work. Each teacher was keen to observe and be observed. The department was strengthened with a high level of discussion and collaboration. The Tutor was used in the discussions to provoke and stimulate debate about the nature of teaching and learning. This department quickly became committed to the CAME approach because the training model impacted their teaching, rather than because of the potential examination improvements promised.

School 3.

Although this school had students achieving high levels of academic success, the department had a problem with communication. The teachers were teaching chemistry, physics and biology separately, not as integrated science as it is in most 6th and 7th grades in Britain. There was little effective discussion about teaching and learning at the departmental meetings. When the Tutor first attended the departmental meeting, he had a rather negative experience. CASE was allocated to the last item on the agenda and limited to a five-minute outline of the project. Nonetheless, the introduction of CASE caught the attention of one subject head. He became keen to modify the culture within the science department, and he saw CASE as a vehicle by which this might be achieved. He secured the principal's support and invited the Tutor to demonstrate a series of CASE lessons for the teachers. Following this experience, the majority of teachers in the department began to engage in regular reflective dialogue. This dialogue began to take place during departmental meetings, with the results that three years down the line, the departmental culture had significantly changed. Staff members are now willing to observe each other and be observed. On school visits by the Tutor, several teachers are keen to discuss recent lesson experiences and to brainstorm future lesson plans and ideas.

School 4.

Inspectors had criticized the science department at School 4 for their poor understanding of pedagogy and their limited use of different teaching and learning styles. In the first year, the Tutor worked with two teachers piloting the CASE materials. The following year, the Tutor did demonstration teaching for all the teachers in the department.

The teachers wrote notes and discussed each lesson initially with the Tutor and later with the experienced CASE teachers. During these discussions, the Tutor and a CASE experienced teacher agreed to focus on different areas of discussion. One person focused on the cognitive agenda while the other focused on the social agenda. The result over the first term was a real change in the level of discussions among the members of the department. The discussions moved from an abstract level to one where actual evidence from lessons was shared. All members of the department could contribute to these discussions.

A Consultant Model

One member of the first cohort of Tutors' programs (1991-2) participated while he was employed as an Authority Advisor. Shortly thereafter he took early retirement, and since then has been running a range of CA training programs in the North of England working as an independent consultant. He is experimenting with a somewhat different technique for coaching in which teachers send video recordings of themselves teaching and he provides detailed written feedback on the videotaped lessons. This process is still being evaluated. If it can be shown that it provides coaching as effectively as the normal face-to-face method then it will be worth developing as a significantly more economical approach.

Monitoring, Accreditation, and Maintenance

CA work is now becoming quite extensive throughout the United Kingdom. As well as the work in England, some of which has been described here, many Authorities in Wales are actively engaged in CA Tutor programs, there are four CASE Tutors established in Northern Ireland, and the first National Scottish CA Convention was recently held in Stirling. Gratifying though this widespread enthusiasm for CA is, it does bring with it a set of concerns about monitoring and maintaining the quality of training. At the present time we have barely begun to address this issue in a systematic manner, but here is one approach:

A *CASE Network* has been established as a users' group independent of the initiators at King's College and free of commercial interests. The Network is developing as a professional body of Tutors and teachers for disseminating information about CA. However, its most important role in the context of monitoring is to produce an agreed upon set of criteria for the accreditation of CA Tutors. The Network will have a professional affairs committee to oversee this accreditation process and in the future any potential client of CA training will be able to ensure that Tutors they employ meet the standards of experience and training set by the Network. Built into the accreditation criteria is a requirement for re-accreditation every few years so as to ensure the maintenance of training standards.

Cognitive Acceleration for Elementary Schools

Finally, we should mention a new project still in the early experimental stage that is likely to cause considerable headaches on the professional development front. This project examines the possibilities for CA with five-year-olds. This is not the place to provide detail of this project, which has yet to produce any results. Enough work has been done, however, to indicate that the professional development program will offer a real challenge. Primary schools do not have departments as secondary schools do, and therefore, teachers act at a far more individual level. Furthermore, these teachers are frequently moved from one grade to another, and often teach for only a few years before moving on to other things. All of these circumstances mean that it is difficult to know how to design the professional development effort. At this time, we suspect that the answer will be a multi-level one. It will involve work with individual teachers, additional work at the school level involving subject coordinators and principals, and also work with the establishment of an Authority-wide structure for continual induction of new teachers as they join the system. Solving this problem is offering us a challenging, but exciting, task.

Conclusion

Here we have tried to present a sense of the complexities involved in introducing a nationwide shift in pedagogic practice. We have developed a range of delivery mechanisms that aim for flexibility and the recognition of individual differences in needs at the teacher, school, and regional levels. In spite of the variations, there are some constant features we take to be essential for the development of teachers' ability to raise student cognitive levels. These constants include allowing up to two years to work with teachers to establish permanent change, an emphasis on the underlying theory of constructing thinking capability, and a commitment to provide professional development to teachers within their schools. Whatever the aims of a particular program may be, we believe that these constants are worthy of serious consideration by anyone responsible for the professional development of teachers.

References

Adey, P. (1993). *The King's-BP CASE INSET pack.* London: BP Educational Services.

Adey, P. (1997). *Factors influencing uptake of a large scale curriculum innovation.* Paper presented at the AERA Annual Conference, Chicago.

Adey, P., Dillon, J., & Simon, S. (1995). *School management and the effect of INSET.* Bath: European Conference on Educational Research.

Adey, P., & Shayer, M. (1993). An exploration of long-term far-transfer effects following an extended intervention programme in the high school science curriculum. *Cognition and Instruction, 11*(1), 1 - 29.

Adey, P., & Shayer, M. (1994). *Really raising standards: Cognitive intervention and academic achievement.* London: Routledge.

Adey, P., Shayer, M., & Yates, C. (1992). *Thinking science - U.S. edition.* Philadelphia: Research for Better Schools.

Adey, P., Shayer, M., & Yates, C. (1995). *Thinking science: The curriculum materials of the CASE project.* (2nd ed.). London: Thomas Nelson and Sons.

Adhami, M., Johnson, D. C., & Shayer, M. (1997). Cognitive development and classroom interactions: A theoretical foundation for teaching and learning. In D. Tinsley & D. Johnson (Eds.), *Secondary school mathematics in the world of communication technology: Learning, teaching and curriculum.* London: Chapman Hall.

Adhami, M., Johnson, D. C., & Shayer, M. (1998). *Thinking mathematics: The curriculum materials of the CAME project.* London: Heinemann.

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process.* Chicago: Henry Regnery.

Feuerstein, R., Rand, Y., Hoffman, M., & Miller, M. (1980). *Instrumental enrichment: An intervention programme for cognitive modifiability.* Baltimore: University Park Press.

Fullan, M. G., & Stiegelbauer, S. (1991). *The new meaning of educational change.* London: Cassell.

Gruber, H. E., & Vonèche, J. J. (1977). *The essential Piaget.* London: Routledge and Kegan Paul.

Joyce, B., & Showers, B. (1995). *Student achievement through staff development.* (2nd ed.). New York: Longman.

Pinker, S. (1997). *How the mind works.* London: Penguin Press.

Shayer, M. (1996). *Long term effects of cognitive acceleration through science education on achievement: November 1996*: Centre for the Advancement of Thinking.

Shulman, L. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher,* **15** (2), 4-14.

Stoll, L. (1992). Teacher growth in the effective school. In M. Fullan & A. Hargreaves (Eds.), *Teacher development and educational change*, (pp. 104-122). London: Falmer Press.

Vygotsky, L. S. (1962). *Thought and language*. Cambridge, MA: MIT Press.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Zeichner, K. M., & Tabachnick, B. R. (1991). *Issues and practices in inquiry-oriented teacher education*. London: The Falmer Press.

8

Teacher Leadership Development as a Critical Component of Systemic Reform: the San Joaquin Valley Mathematics Project

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Since its inception in 1982, the California Mathematics Project (CMP) has sought to develop the mathematics skills and leadership capabilities of K-12 teachers through intensive summer institutes and a variety of academic year programs sponsored by regional CMP sites. This chapter focuses on ways in which one of the fifteen regional CMP sites, the San Joaquin Valley Mathematics Project (SJVMP), facilitates and supports the development of mathematically competent, professionally knowledgeable, and actively involved teacher leaders. To provide a meaningful context for discussing the SJVMP, the chapter first provides a brief historical overview of the educational and political environment within which the CMP was established and in which it developed and flourished during its first 15 years.

California's Decade of Systemic, Progressive School Reform

In 1983, *A Nation at Risk* was published, stimulating a national effort to improve K-12 education. By the mid-1980s, California's Department of Education–rallying under the enthusiastic leadership of State Superintendent of Public Instruction Bill Honig–had initiated the establishment of a coordinated, systemic reform of curriculum, instruction, assessment, and professional development. For the next decade, California was widely viewed as a leader in progressive education. The major elements of California's systemic reforms are described below, with an emphasis on the professional development component and with particular focus on mathematics.

Curriculum and Instruction

Between 1985 and 1992, curriculum frameworks were developed and published by the California Department of Education for each of the subject matter areas required for high school graduation. Each of these guides was influenced by research, professional judgment, and documents produced by professional organizations such as the National Council of Teachers of Mathematics. The frameworks promoted "critical thinking and conceptual understanding; problem solving based on real-life problems; meaning-centered rather than memorization-oriented learning; active learning and activity-based instruction; contextualized learning which makes connections to students' experiences; collaborative learning in groups, and interdisciplinary learning" (Intersegmental Coordinating Council, 1993, p. 3).

In 1991, the California Department of Education sponsored the development of *Seeing Fractions*, the first of a number of mathematics "replacement units" designed to (a) provide an example for textbook publishers of curriculum aligned with the 1992 *Mathematics Framework* and to (b) provide teachers with the first of many *Framework*-aligned units to replace or supplement chapters in current mathematics textbooks. The state also sponsored numerous workshops throughout California to familiarize 5th-grade teachers with *Seeing Fractions* and with the new instructional expectations contained in the new *Mathematics Framework*. Curriculum writing flourished during the early 1990s. Numerous replacement units and integrated high school mathematics courses were developed—all focusing on promoting students' mathematical reasoning and understanding, and all incorporating hands-on activities, technology, problem solving, writing, performance assessment, and collaborative learning. A number of teacher leaders were involved in the writing, field testing, and implementation of these curricular units/courses. Materials approved during the 1994 California K-8 mathematics textbook adoption featured many innovative curricula that were developed in accordance with the Instructional Materials Criteria included in the 1992 *Mathematics Framework*.

To complement the new subject matter frameworks, four seminal reports covering the K-12 grade span were produced by task forces convened by the California Department of Education (CDE): *Here They Come, Ready or Not!* (1988); *It's Elementary!* (1992); *Caught in the Middle: Educational Reform for Young Adolescents in California Public Schools* (1987); and *Second to None: A Vision of the New California High School* (1992). These documents (available from http://www.cde.ca.gov/cdepress/presource.html) promoted a "rich, meaning-centered, thinking curriculum," emphasizing reform initiatives such as developing "students' higher order thinking skills… [as opposed to utilizing] the conventional linear lockstep approaches" (Intersegmental Coordinating Council, 1993, p. 21). Teacher networks (e.g., the California Alliance for Elementary Education and the California High School Network) supported the dissemination, application, and implementation of the reform ideals presented in these documents.

Assessment

Another component of the state's systemic reform efforts was the development of a new assessment system aligned with the progressive tenets of the curriculum frameworks. In 1991, Senate Bill 662 (Hart) established the California Learning Assessment System (CLAS), replacing the California Assessment Program (CAP). State Superintendent of Public Instruction Bill Honig believed that the new performance-based test would create opportunities for students to demonstrate their understanding of the subjects tested rather than assessing how well they could guess on a traditional multiple choice test. From 1991 to 1993, CLAS developed and field-tested the mathematics, science, history–social science, and English–language arts tests for grades 4, 5, 8, and 10. The mathematics portion incorporated open-response items and a relatively small number of multiple choice items designed primarily to assess a student's conceptual understanding, number sense, and ability to solve application problems, as opposed to his or her computational proficiency. In 1993 and 1994, thousands of teachers received instruction on how to use and design rubrics to assess the open-response items on the CLAS tests (and similar assessments). In 1994, over 3000 teachers scored more than three million pieces of student work. Many teachers considered the CLAS instruction to be an extremely important and enlightening professional development experience. The focus on analyzing students' solutions to nonroutine problems provided teachers with insight into their students' reasoning and their understanding–or lack of understanding–of mathematics concepts. (The assessment system was not without controversy, however, especially from proponents of a more traditional accountability system. In September, 1994 Governor Pete Wilson vetoed a bill that would have authorized the continuation of CLAS, thus eliminating the program.)

Professional Development–The California Subject Matter Projects

The final element of California's systemic reform plan in the 1980s and early 1990s was the establishment of a statewide professional development system to provide a coordinated approach to staff development and to build teacher capacity to implement the pedagogy and content of the curriculum frameworks (Carlos & Kirst, 1997). This professional development system became known as the California Subject Matter Projects (CSMPs).

CSMP history (1981-1998). The original model for the CSMPs was the Bay Area Writing Project (BAWP), which held its first summer institute in 1974 at the University of California, Berkeley. This institute drew together expert teachers from all grade levels to examine critically the research on writing, to practice and hone their own writing skills, and to share their most effective techniques for teaching writing (University of California Office of the President, 1994). In 1981, funding was provided by the California legislature to establish a statewide network of sites based upon the BAWP model, creating the California Writing Project (CWP). The following year, the University of California supported legislation (SB 424) that instituted the California Mathematics Project (CMP). By the end of 1983, eight regional CMP sites had been established (California Postsecondary Education Commission, 1986).

In 1987, a state-commissioned evaluation of professional development concluded that in general there was little coherence or systematic planning in the inservice education that teachers received in California, and that staff development was fragmentary and tended to support traditional school structures and teaching strategies (Little, Gerritz, Stern, Guthrie, Kirst, & Marsh, 1987). The report named two notable exceptions—the CWP and the CMP, which were recognized as containing program elements that led to significant changes in teachers' thinking and practice.

In response to this study, legislation was proposed and passed in 1988 (SB 1882–the Professional Development Act) that established five more California Subject Matter Projects for subjects required for high school graduation. A fiscal augmentation in 1992 led to the expansion of existing sites, the development of new sites, and the creation of two new CSMPs for a total of nine projects (Arts, Foreign Language, History—Social Science, International Studies, Literature, Mathematics, Physical Education—Health, Science, and Writing). The goal (though rarely met) was to establish sites throughout the state so that no California teacher would have to drive more than 100 miles to attend CSMP-sponsored activities. A recent report (Inverness Research Associates, 1998) noted that the CSMPs "provide direct support to over 67,000 teachers every year" and that "one-fifth of all California teachers are involved in at least one Subject Matter Project each year."

CSMP goals. The CSMPs have been administered by the University of California under the direction of a Concurrence Committee since 1988. In 1990, this committee developed a set of guiding principles for all of the projects. In summary, projects were expected to (a) use a "teachers teaching teachers" model, where instructional and content expertise was shared among participating teachers; (b) hold 2-4 week summer institutes and a series of academic year follow-ups focusing on subject matter content and the latest ideas in the discipline and their classroom applications; (c) foster and sustain teacher leadership by supporting curriculum development and article writing, encouraging leadership in regional and statewide professional associations, providing guidance in grant development and research, and providing and promoting opportunities for leadership at the project site and on school, district, county, and/or state curriculum and instruction committees; and (d) maintain a regional, discipline-based network consisting of K-12 teachers and college/university faculty (Bartels, 1990; Intersegmental Coordinating Council, 1993).

A major aspect of the CSMPs, therefore, is to develop and sustain subject matter area *teacher leaders*. Bohlin (1999) has characterized teacher leaders as those teachers who have made a commitment to improving their knowledge of [a particular subject matter area] and exemplary instructional practices and actively engage in helping other teachers to do the same. Little (1988) has stated that "it is increasingly implausible that we could improve the performance of schools…without promoting leadership in teaching by teachers" (p. 78). Accordingly, a recent survey of the CSMPs stated that these "teacher leaders are the horsepower for educational reform," serving in seven primary roles: (a) workshop presenters in schools and districts, (b) members of school site leadership teams, (c) leaders for local school restructuring efforts, (d) district or state-designated mentor teachers, (e) team teachers or peer coaches in their schools, (f) subject matter specialists for local schools, and (g) curriculum developers for schools and districts (Stokes, Hirabayashi, & St. John, 1998).

The California Mathematics Project. The CMP network is comprised of fifteen regional sites based at either a University of California or a California State University campus. Faculty members serve as the sites' Principal Investigators, with a majority also serving as Project Directors. Each regional site is expected to provide leadership in mathematics education to the K-12 schools located in the site's service area. This goal is primarily accomplished through the development of a cadre of teacher leaders with the knowledge, confidence, and skills to provide leadership at their school sites and in their districts.

Although each site is uniquely administered and defines its own goals and objectives, all sites subscribe to a set of common beliefs–e.g., the importance of mathematics competency; the belief that all teachers are capable of becoming more knowledgeable, confident, and competent mathematics educators; the belief that teachers have the capacity for leadership and must play a central role in leading efforts to improve education; and the vision of mathematical power for all students (California Mathematics Project, 1994). Sites "create a professional home for teachers that is based upon a culture of inquiry, experimentation, and reflection" (Medina & St. John, 1997, p. iv) that extends throughout the life of the project. Each CMP site hosts a two- to four-week initial summer institute for an average of 30 new participants, and most sites also sponsor a "Tier II" leadership institute for project "alumni." A variety of academic year follow-up experiences (e.g., study groups, action groups, workshops, conferences, and electronic networks) nurture the development of teacher leadership among site participants. The CMP model is one of long-term, sustained professional development, in contrast to a conference or a "one-shot" workshop. Experienced and interested teacher leaders often assume leadership roles at the Project site, becoming site co-directors, institute coordinators, study group leaders, regional coordinators, or institute instructors. They are also given many opportunities to assume local, regional, and/or statewide leadership roles in mathematics education via involvement in professional organizations (e.g., the California Mathematics Council and its affiliates) and in activities related to the state's curriculum, instruction, and assessment initiatives.

This paper has provided a brief summary of California's progressive reforms of the 1980s and early 1990s with a focus on the California Subject Matter Projects. The next section provides a more in-depth look at one site of the California Mathematics Project–the San Joaquin Valley Mathematics Project (SJVMP)–to examine how that site develops and sustains teacher leaders. Quotations from Summer Institute journals and from post-Institute assessments are woven into the description to help paint a picture of the SJVMP experience from the perspective of participating teachers.

The San Joaquin Valley Mathematics Project

The San Joaquin Valley Mathematics Project is based at California State University, Fresno (CSUF), and serves teachers from five counties throughout California's Central Valley—a vast 22,405 square mile agricultural area consisting of 162 school districts, over 700 schools, and over 350,000 students who collectively speak over 100 different languages. Initial funding for the SJVMP was received in 1988. The staff consists of (a) a Project Director/Principal Investigator and two Co-Principal Investigators who are CSUF faculty members, (b) a Coordinator of Professional Development, (c) three Regional Coordinators, and (d) twelve Grade Level Leaders. All of the non-university staff are classroom teachers or curriculum specialists who have assumed leadership positions in the Project after being involved with the Project for at least a year. (More details may be found in the section on Academic Year Support.) The sections that follow provide details about the Summer Institutes and the academic year support for participants, with a focus on the ways the SJVMP helps to develop teacher leadership.

Initial Summer Institute

Each year since 1989, approximately thirty-five K-12 teachers and administrators have applied for and been accepted to participate in the two-week SJVMP Summer Institute and in a variety of follow-up experiences. Due in part to the geographic expansiveness of the service area, the first week of the Summer Institute is residential, a model that has proven to be especially powerful in facilitating professional growth and for developing close, supportive collegial relationships. The second week of the Summer Institute is nonresidential. Participants commute to a site near the geographical center of the SJVMP service area for five full-day sessions.

The two-week Institute is the first experience teachers have as formal members of the SJVMP. This Institute, particularly the residential component, provides a crucible within which teachers (a) examine and reflect critically on their teaching practice and their beliefs about teaching and learning (journal writing is an important element in facilitating reflection during the week), (b) gain a deeper understanding of mathematics concepts and how those concepts span the K-12 spectrum, (c) learn new approaches and techniques for helping their students develop a deep understanding of mathematics concepts and procedures, and (d) form close, supportive collegial relationships. It is an intense week that a participant referred to as "total math immersion."

It is also an opportunity for members of the SJVMP staff to hone their leadership skills. The Institute is traditionally coordinated by the Project Director and planned in detail with the Project staff (3 faculty and 16 teacher leaders). Staff members who have participated in the planning and delivery of previous institutes serve as mentors for any new staff members, teaming with these new leaders to plan and deliver sessions at the Institute. Each staff member is expected to actively participate in at least three days of the Institute. Pooling resources, information, ideas, experiences, and expertise during the planning of the Institute and follow-up activities is an excellent professional development opportunity for both the university faculty and the teachers on the staff.

Residential Component

The residential week is held at a retreat center near Yosemite National Park from noon on a Sunday in June or July through the following Friday afternoon. Residential institute days typically stretch from 8:00 a.m. until 9:00 p.m., with three one-hour breaks for meals, reflection, and walks. The retreat setting allows participants a rare opportunity to "get away from day to day responsibilities and 'chaos' and focus on mathematics." A variety of experiences are provided to instruct, challenge, and support participants.

Morning K-12 sessions. During the mornings, participants work in heterogeneous grade-level groups facilitated by SJVMP staff teams. They pore over professional documents such as *Everybody Counts* (National Research Council, 1989), the NCTM *Standards* documents (National Council of Teachers of Mathematics, 1989, 1991), the *Mathematics Content Standards for California Public Schools* (http://www.cde.ca.gov/board/mcs_intro.html), and the two most recent versions of the California *Mathematics Framework* (CDE, 1992, 1999: http://www.cde.ca.gov/cilbranch/eltdiv/mathfw.htm). Issues are raised, discussed, and debated. Equity and access concerns are infused into these discussions.

During the morning sessions, participants also experience mathematics as learners and as problem solvers in a collaborative setting. Professors pose open-ended problems and investigations that serve to illustrate how numerous mathematics concepts can be embedded in the exploration, solution, and extension of a seemingly simple problem such as "How many squares can be formed on your geoboard?" or "How can you determine the height of one of the redwoods in this grove, and approximately how many cabins could you construct from it?" In debriefing, participants are amazed at the variety of solution strategies (and sometimes unique interpretations) presented by their peers, as well as by the number of mathematics skills and concepts that can be embedded in one problem. In addition, working in heterogeneous K-12 groups allows participants to (a) acquire a broader perspective of common issues and challenges that permeate all levels of education, (b) develop a greater understanding of and respect for teachers at all grade levels, and (c) become knowledgeable of how mathematics concepts are developed across the grade levels, as evidenced by one 9th grade teacher's comments:

> *One of the most amazing realizations I had this week was how factors and products could be demonstrated visually/physically using base ten blocks (for whole number products) and algebra tiles (for products of variables). I had tears in my eyes as I finally understood—could SEE—the relationship between partial products in the multiplication algorithm and 'FOIL'! The fourth-grade teacher at my table and I felt a new connection in what we were teaching students...5 years apart!*

Afternoon grade-level sessions. At least four hours each afternoon are spent in "Grade Level [K-2, 3-5, 6-8, and 9-12] Homes" where teachers can focus on the mathematics content and pedagogy for their particular grade level. The pair of lead teachers (SJVMP staff) who coordinate each "home" create an inviting environment in a break-out room equipped with tables, chairs, a video player, and white boards. Each room is filled with a plethora of professional books, curriculum units, manipulatives, and student projects. The Grade Level Homes provide participants with the opportunity to dialogue in depth with other teachers at their grade level and to engage in a wide variety of hands-on activities to gain a deeper understanding of mathematics concepts and ways of teaching for conceptual understanding.

In the Grade Level Home, model lessons are taught by one of the lead teachers and debriefed by the other lead teacher who demonstrates peer coaching techniques. Participants then practice teaching the concept to a partner, who critiques the lesson. Mathematics concepts that are taught at participants' grade levels (and 2 years beyond) are explored in depth. Effective uses of manipulatives and technology are demonstrated and practiced. Participants discuss honestly the challenges they face in the classroom and brainstorm solutions. Videotaped case studies are viewed and children's mathematical understanding is analyzed. Participants share "best practices." The "sharing of ideas with committed, talented teachers from many different districts" is consistently mentioned in journals as being one of the most valuable aspects of the Project, as is the opportunity to tackle challenging mathematics problems in a "safe" environment where risk-taking and grappling with concepts is expected and supported.

Darling-Hammond (1998) has stated, "teachers need deep and flexible knowledge of subject matter, many representations of ideas, and strategies for connecting ideas" (p. 5). The Grade Level Homes are an effective place to build these competencies. A fifth grade teacher wrote,

> *I never had any idea what division of fractions meant or why you inverted and multiplied. It didn't make any sense that you could get a whole number from dividing fractions. Seeing how many sixths made up a half using the pattern blocks for 1/2 ÷ 1/6 was the first of a bunch of big a-ha's this week! I even called my wife and told her about it. Math does make sense—you just have to know the language and actually own the concept, not simply memorize the procedure. I'm much more confident in my ability to use my common sense to figure out math problems or even re-derive formulas. What's that word? I'm mathematically 'empowered'!*

Evening activities. After dinner, participants spend approximately two hours in their Grade Level Homes, critically analyzing a variety of mathematics curricula and aligning their own textbooks and activities with the California mathematics content standards. This exercise helps participants to be aware of and focus on the mathematics concepts contained in the activities they utilize in their classes, thus helping to avoid "activities for activities' sake." Learning to effectively debrief lessons with their students through probing questions is also an important component of the participants' leadership development experience.

After the evening sessions, participants gather to watch math-related videos such as *Good Morning, Miss Toliver* (FASE, 1993), *Mathematics–What are You Teaching My Child?* (Scholastic, 1994), and *The Story of Pi* (and others from the Project MATHEMATICS! series: http://www.projmath.caltech.edu/); to play games such as Set, Mancala, or Tri-Ominoes; to read; or to share unique skills and abilities during "talent night." Some gather for tutorials on the use of their laptops (on loan from the California Technology Assistance Project) or to surf the Web. Most engage in conversations about teaching that typically run late into the evening.

Community building. An important element of effective professional development is the fostering of a close-knit, supportive learning community. In such an environment, trust is developed and risk-taking is encouraged (Loucks-Horsley, et al., 1998). Fullan and Hargreaves (1998) refer to the importance of "interactive professionalism" in their essay on teacher change. The Summer Institute lays the groundwork for fostering a community where unanimity of purpose exists–the development of a deeper personal understanding of mathematics, a belief in the value of developing mathematical power in all students, and a desire to take more of a leadership role in mathematics education. The social networking of the teachers during sessions, meals, hikes, and late-night gatherings in the cabins fosters a deep sense of mutual respect and concern. Many strong, lasting professional friendships have been forged through late-night conversations between roommates and among those venturing out to the main meeting room during the late evening hours for fellowship and discussions over math games or videos. One participant referred with fondness to her "inspirational professional support group" in her post-Institute assessment.

A variety of more structured activities to develop a sense of community are incorporated into the first week. Each participant's photo is glued to a piece of colored construction paper and mounted on the wall in one of the meeting areas. This "class quilt" serves as a message board where comments are surreptitiously left for "classmates." Each person has a secret "Math-Pal" and plans small surprises for him or her during the week. "Math Songs" such as "How do you solve a problem like division?" (a take-off on "How do you solve a problem like Maria?") are sung during meals. A class tee-shirt is designed each year by a participant-selected committee, ordered, and delivered on the last day of the Institute. (These shirts are often worn at follow-up activities and at mathematics conferences.) Engraved name badges with magnetic backs plus pens, note paper, and water bottles containing the SJVMP logo are provided for each participant as tangible mementos of the Summer Institute and membership in the SJVMP "family."

Non-residential Component

The second week of the Summer Institute builds upon the first. From 8:00 a.m. until 5:00 p.m. daily, participants expand their understanding of mathematics and effective teaching strategies. In addition, recognized leaders in mathematics education and SJVMP teacher leaders give presentations on a variety of topics selected to expand the professional knowledge base and professional contacts of the new SJVMP participants. These topics include the following: becoming an informed consumer of educational research, developing successful grant proposals, professional organizations and online journals, writing for publication, analyzing the components of the new state assessment system, the political landscape of K-12 math education, organizing extracurricular math programs, and opportunities for professional involvement.

Participants spend several hours in a computer lab each day learning ways to infuse technology into their curriculum and becoming familiar with Web sites important to their ongoing development as leaders in K-12 mathematics education. They learn presentation programs such as Microsoft PowerPoint and create an electronic presentation for their school site faculty about an aspect of their Summer Institute experience. Whenever possible, participants access electronic versions of documents and resource materials rather than print versions. For example, each of the three grade-level TIMSS reports, *Pursuing Excellence*, are available online at http://nces.ed.gov/timss/ . Participants delve into the report closest to their instructional grade level and discuss the findings in heterogeneous grade level groups. This sets the stage for their viewing and analyzing vignettes of Japanese, U.S. and German classrooms from the TIMSS video project.

School sites are expected to provide participants with Internet access so they can continue professional networking and can access current information. Participants are also urged to join professional associations and to have their schools become institutional members of NCTM. To help these emerging teacher leaders and workshop coordinators develop their presentation skills, they receive and discuss books such as *Sharing Your Good Ideas: A Workshop Facilitator's Handbook* (Sharp, 1993). They practice presentations that they plan to give at their school sites on some aspect of mathematics education. In short, they prepare for their emerging roles as mathematics education leaders.

Assessment of the Summer Institute Experience

At the conclusion of the two weeks, participants often express enthusiasm about their Summer Institute experience:

> *I'm exhausted, but I don't want to go. This has been a powerful experience, both professionally and personally. What a stimulating group! I have made many new friends whom I rightly respect. I have packed my brain with hours of information.*
>
> *It was energizing to be around so many people who were excited about mathematics. I see myself more as a professional with new responsibilities to my students and my staff.*
>
> *I feel that every session and experience was a vital necessity for improving math instruction in schools. We received some powerful messages from this project and my somewhat passive attitude has been transformed into an advocate for equitable, challenging instruction in mathematics.*

They also make comments about the intensity of the experience: "*These last two weeks [at Math Camp] have been one of the best years of my life!*" Despite the intensity of the Summer Institute (perhaps because of this intensity), participants experience major shifts in their beliefs about the nature of mathematics, about themselves as learners of mathematics, and about what it means to teach mathematics. Typical comments are: *"This is the best professional development* *experience I have ever had"* and *"Many people have said that the Math Project has changed their lives—now I know what they mean!"*

A secondary school teacher wrote in her journal,

> *Before I came to the project, I believed that I truly needed to be the 'sage on the stage' and had to be in control of every aspect of the math lesson. I was the expert, knowing and dispensing the most efficient way to solve every problem and to learn every concept. I expected all of my students to understand it the way I did and at my pace. During 'Math Camp,' I realized that I was losing so much by not listening to and learning from the students—how we all have such different ways of perceiving/solving problems and learning math concepts. Math is no longer a cut and dry subject for me. It can and should actually make sense! Students should develop confidence in the 'whys' and 'whens,' not just the 'hows' and 'whats' of math. I can't wait to teach—and learn!--with new eyes and ears!*

An elementary school teacher wrote,

> *I wonder where I would be now if I hadn't felt that I was so dumb in math. Math Camp was the first time that I had experienced hands-on, minds-on learning, not just regurgitation, 'fill and drill' math. I feel so much more confident in my ability to understand and teach math. I also know that I'll never be tied to an adopted math program because I now have so many resources, including my own creative ideas. The SJVMP also gave me the confidence to pursue a master's degree in mathematics education.*

As the passages above indicate, the Summer Institute experience is highly effective in increasing teacher efficacy. Participants leave the Institute with a sense of renewed confidence in their ability to reach all students and a conviction about their ability to make sense of challenging mathematics problems. Castle and Aichele (1994) discuss the importance of teachers developing professional autonomy, a key characteristic of a reflective, professional educator and of a teacher leader. Autonomous teachers are independent, confident, informed decision makers who look for opportunities to keep current professionally and who continually construct and reconstruct what they know about teaching and learning. Their views are not necessarily in alignment with or influenced by policy decisions (Firestone & Pennell, 1997). This characteristic is closely related to the concept of "self-sustaining, generative change"–the continued growth and problem solving of reflective teachers who make "changes in their basic epistemological perspectives, their knowledge of what it means to learn, as well as their conceptions of classroom practice" (Franke, Carpenter, Fennema, Ansell, & Behrend, 1998).

Although most teachers expressed a major shift in their sense of efficacy, professional autonomy, and beliefs about the nature of mathematics and teaching mathematics, some wrote that the Summer Institute experience was of value to them because it was a validation of what they already believe and how they conduct their classes. A finalist for the Presidential Award for Excellence in Mathematics Teaching wrote,

> *For the first time in my 17 years of teaching, I can say that I feel like a professional, not isolated in my own classroom. The greatest gift the Math Project has given me is the ability to empower myself and others. For me, it came in the form of self-belief. Once I saw that my alternative teaching approaches were OK, I began to step out and become a "teacher leader." I felt comfortable sharing ideas with others, at all grade levels.*

In short, the SJVMP Summer Institute helps to develop the leadership potential of participants by providing them with an experience that:

- challenges their perceptions about the nature of mathematics and what it means to be a learner of and effective teacher of mathematics.
- expects them to grapple with engaging mathematics problems and with knotty issues related to mathematics education together with skilled teachers from other school sites and districts.
- helps participants to develop a K-12 perspective on mathematics education issues and mathematics content.
- equips them with knowledge of the latest developments in mathematics education (curriculum, assessment, instruction, legislation, studies, publications, etc.) on the state and national levels.

- deepens their understanding of the mathematics taught at their instructional level(s).
- broadens their repertoire of effective teaching strategies and resources.
- strengthens their presentation skills (including their familiarity with presentation software), as well as their leadership and mentoring/coaching skills.
- presents them with opportunities and encouragement for becoming involved professionally.
- provides a "professional home" – a close-knit, trusted network of colleagues and friends who can provide support, feedback, perspective, and ideas.

The next step in the teachers' leadership development is their participation in academic year follow-up experiences and in a Summer Leadership Institute. Each participant is also placed on an electronic mailing list for daily updates on issues related to mathematics education.

Summer Leadership Institute

Judith Warren Little has stated that "one test of teachers' professional development is its capacity to equip teachers individually and collectively to act as shapers, promoters, and well-informed critics of reforms" (Little, 1993, p. 130). The SJVMP Leadership Institute builds upon the initial SJVMP experience to help achieve this goal. During the middle of the first week of the initial Summer Institute, interested alumni from past institutes attend a four-day residential Leadership Institute at the same retreat center as the Summer Institute. During this Institute, participants

- delve more deeply into the research on mathematics learning.
- strengthen their mathematical content knowledge.
- receive copies of and critically analyze recent articles and documents (e.g., NCTM Yearbooks, NCTM's *Principles and Standards for School Mathematics*–http://standards-e.nctm.org/, and state mathematics standards and frameworks).
- read sections from books such as Stanislas Dehaene's *The Number Sense* (1997) and Marilyn Burns' *Math: Facing an American Phobia* (1998).

- share their successes and challenges.
- continue the professional networking that is an important component of the SJVMP.

A statewide Presidential Award winner wrote that the SJVMP is "a network of professionals who support and raise each other to new heights." A districtwide Teacher of the Year wrote,

> *One truly valuable aspect of being involved with SJVMP is the on-going networking, communicating, and exchanging of ideas with other teacher leaders who aren't just complaining about the way things are, but are building a vision of how things can be.*

The Leadership Retreat kicks off with a welcoming reception and a thematic party incorporating mathematics activities and investigations to give the alumni and new participants a chance to mingle. Then the alumni are given the opportunity to share what participation in the SJVMP has meant to them on a personal and a professional level. The next day, a block of time is allocated for selected alumni to give presentations to new participants, who typically view the alumni as teacher leader role models and "big brothers/sisters in the SJVMP family." A participant wrote, *"It was encouraging and inspiring to hear from the alumni and know that SJVMP isn't just for 2 weeks – it's for the rest of your life!"*

Academic Year Support

Academic year follow-up activities and reunions, as well as e-mail conversations, allow collegial relationships to deepen and strengthen over time. Participants know that they have numerous trusted colleagues upon whom they can call for ideas, advice, information, or commiseration. Wertheimer's adage that "the whole is greater than the sum of the parts" is very much in evidence when talented teachers have the opportunity to brainstorm creative approaches to challenging problems or to develop ideas for conferences or workshops. It is therefore important to give teachers numerous opportunities to reconnect with members of the SJVMP "family" in both informal settings and in more formal conference/ workshop-type settings. Each gathering becomes an opportunity to reconnect, become professionally energized, gain more knowledge about mathematics and mathematics education, and grow as a teacher leader.

Follow-up Meetings and Communication

The Project's Coordinator of Professional Development oversees the delivery of a fall "Super Saturday Sharing Session" where participants from all SJVMP classes meet together throughout the day to share and discuss student work; describe new instructional or assessment strategies they have recently employed; deepen their mathematics content knowledge; and examine new research, mathematics education documents, education policies, and educational opportunities. Three additional Saturday workshops focus on curriculum alignment with the state's mathematics content standards and ways to help students meet challenging standards. Teachers, especially those who have been in the Project for a number of years, believe that an important component of the workshops is an examination of and discussion of children's thinking, reasoning, and understanding, which is consistent with the research of Gabriele, Joram, Trafton, Thiessen, Rathmell, and Leutzinger (1999).

A variety of locally-based follow-up experiences are provided by three Regional Coordinators (RCs) and each of their four Grade Level Leaders (GLLs), all of whom have been selected by the Project Director and Principal Investigators from a pool of SJVMP applicants. In addition to their roles in planning and leading the Summer Institute, each RC and his or her GLLs are responsible for the "care and feeding" of the SJVMP teachers in one or two counties in the SJVMP service area. The Project Director supports the teacher leaders (provides financial resources from the Project budget, advice, needed facilities, etc.) and meets with the teachers on at least a monthly basis. E-mail serves as an important avenue for communication among the leaders as they plan and coordinate meaningful professional development activities for SJVMP participants and for other teachers in their region.

Each Grade Level Leader is responsible for communicating via telephone and e-mail with all of the SJVMP participants in their designated county or counties who teach in one of the four grade-level spans: K-2, 3-5, 6-8, or 9-12. The GLLs offer support and resources, collect any updates on teaching assignments or addresses for the Project's database, and serve to connect participants to the SJVMP "family." The GLL also solicits ideas for needed inservices, and is responsible for planning and delivering at least three half-day mathematics workshops a year, especially targeted for teachers in that grade-level span. These workshops are typically led by SJVMP alumni who are eager for the opportunity to develop further their presentation and leadership skills.

Each Regional Coordinator is responsible for (a) planning a full-Project reunion (consisting of a reception, meal, mathematics program, and professional updates) at a professional conference (e.g., the California Mathematics Council's Central Section conference or the Bakersfield Mathematics, Science, and Technology Conference); (b) coordinating and supporting the activities of the GLLs in his or her region, and (c) hosting an annual Administrator Evening event for SJVMP participants and their guests (principal, superintendent, and/or school board member). At these dinners, administrators are given the chance to learn more about the SJVMP and Project-related experiences of their teachers, to recognize the contributions of the SJVMP participants at their school sites, to receive updates regarding mathematics education (e.g., curriculum, assessment, pending legislation, national trends, and research), to solve mathematics problems along with their teachers, and to be recognized for their support of the Project and their teachers' leadership efforts. Each administrator leaves with a file containing information about the SJVMP, regional mathematics education opportunities, and salient articles or resources. Interested administrators also receive a computer disk containing a searchable 60-field "Professional Development Providers" database containing the names of all SJVMP teachers who are interested in delivering assistance to school sites or districts on a wide variety of math-related topics. Finally, administrators are given the opportunity to be added to the Project's e-mail distribution list to receive articles and news regarding mathematics education.

The role of the principal and other key administrators is vital "for professional development to move from learning to changes in classroom practice"(Loucks-Horsley, Hewson, Love, & Stiles, 1998), as well as for the support of leadership activities. In addition to the Administrator Evening activities, letters from the Project Director and Principal Investigators to principals thanking them for their support and requesting feedback are mailed periodically.

Online newsletter

For ongoing professional growth, it is also vitally important that members be kept apprised of the latest information and opportunities related to mathematics education. Fullen and Hargreaves (1998) write, "redefining the teacher's role includes a responsibility to become knowledgeable about policy, and about professional and research issues in the wider state, provincial, national, and international arenas." For a number of years, the SJVMP newsletter, "Summing Up," was a key source of information for members of the mathematics education community. To provide a much more cost-efficient and timely way to share pertinent information, the SJVMP mathematics education e-mail network was born. The Project Director collects, annotates, and disseminates via e-mail articles and announcements pertaining to mathematics education, URLs of newspaper and journal articles, details of professional development opportunities, and Project member updates on a daily basis. Over half of the SJVMP teachers are part of this network, and over 400 more individuals (including curriculum coordinators, consortia directors, superintendents, professors, project directors, and interested individuals from the national and international mathematics education community) are on the expanded distribution list and receive a subset of the messages sent to SJVMP participants. Feedback from participants (and their administrators) has been highly supportive of this online newsletter, which helps to keep readers on the cutting edge of developments and leadership opportunities in mathematics education.

> *The email hotline is an incredible resource for me. The news and articles keep me amazingly well-informed. I forward the messages to key administrators in my district and also print them out and put them in a notebook that I leave in the teacher's lounge.*
>
> *Knowing what's happening in the wider educational arena gives me a more authoritative voice and chance to help shape the vision of the district in which I work. Being in touch with the leading edge of educational research, teaching innovation, and current events has given me the confidence to share my expertise and viewpoint in a professional way, and it has gained for me the respect and validation of my colleagues and administrators.*

Evidence of Teacher Leadership

SJVMP participants have enthusiastically commented that the Project has given them an exciting new vision as well as a deeper understanding of mathematics content and its instruction. Teachers are implementing innovative programs of mathematics instruction in their classes and in their schools. In addition to opening participants' eyes to the world of mathematics reform, the Project is credited with providing a wide array of opportunities for professional growth. Numerous leaders in California's Central Valley credit their leadership positions and professional recognition to their participation in the SJVMP.

> *Before the Math Project, I was a really good elementary school teacher, bordering on excellent, experimenting on my own with manipulatives, problem solving, etc. But I was on my own. Very little information on good resources. Clueless about the fact that there were other teachers on the same road. Basically minding my own business. Hiding from administrators who might object to my methods. Afterwards, wow! I was a better teacher, but I also started bugging administrators for more money for math resources, leaving copies of articles and great activities in teachers' mailboxes, doing mini-inservices at teachers' meetings, applying for and getting mentorships, getting on curriculum committees and math textbook adoption committees. Because of my increased visibility and involvement, I was one of only three California teachers to be selected by NASA to attend a 2-week workshops at their Jet Propulsion Lab in Pasadena and was also named district Teacher of the Year.*
>
> *Before I became a member of the SJVMP, I was considered a strong math teacher, but I was isolated. The classroom was as far as my professional life went. The Math Project opened my eyes to a plethora of opportunities and opened dozens of doors for me! My world has expanded dramatically! My life is full of new challenges, avenues for professional growth, and dozens of new professional colleagues and friends. I guess you could say I am "professionally self-actualized!*
>
> *My SJVMP leadership training inspired me to do many more activities and unit Projects with my students; share them with other teachers at conferences; share them with my math department (which led to me being elected Department Chair at both schools at which I've taught); share them with*

> *thousands of math teachers through the state math journal, the ComMuniCator; share my time by being on statewide math committees, and so on.*

Administrators have been highly supportive and enthusiastic about the effect of Project participation. Teachers are expected to take a wide variety of leadership roles at their school site and in their districts. Administrator surveys collected by Bohlin (1996) included the following comments:

> *Every teacher comes out stronger and more proficient in curriculum and assessment. The experiences empower teachers to make significant changes in their classrooms and schools.*
>
> *As Director of Curriculum, I have seen four of our teachers participate in the project. They have all served in leadership roles including mentorships, math committees, presentations, Program Quality Review for math, and officers in math organizations."*
>
> *C--- has gained confidence in his field. He is willing to share his knowledge with others and to move the department in the direction of the frameworks. Student interest is high.*
>
> *I think that this project is wonderful. I hope to send others who will take risks in the classroom and share with others.*
>
> *M---'s leadership is changing the way math instruction is delivered at this school. He is an excellent teacher who is now a teacher of teachers.*
>
> *It's been a pleasure to work closely with a teacher who is now on the 'cutting edge' of mathematics instruction.*

Following is a sample of recent leadership roles and professional recognitions that teachers have received in the years following their initial participation in the SJVMP:

- Four SJVMP teacher leaders have received the statewide Presidential Award for Excellence in [Elementary or Secondary] Mathematics Teaching during the past three years; three more have been finalists. Two teachers received district Teacher of the Year honors in 1999.
- A team of a dozen SJVMP teachers from Visalia Unified School District was instrumental in conceptualizing an NSF Local

Systemic Change grant that was recently funded for $3.8 million; four members of the development team are currently serving as full time lead teachers for that project.

- SJVMP teacher leaders serve in key leadership roles on the mathematics inservice team for Fresno Unified School District's (FUSD's) NSF-funded Urban Systemic Initiative; an SJVMP teacher was selected as the district's Director of Research and Evaluation.
- A team of SJVMP teacher leaders co-directed a statewide conference on equity in mathematics education.
- Three NCTM regional affiliates have been established or revitalized by SJVMP teachers.
- The immediate past-president of the California Mathematics Council (CMC) is a former co-director of the SJVMP; a number of other SJVMP teacher leaders have been elected to serve on the CMC statewide or regional boards in recent years.
- Three SJVMP teacher leaders' classrooms were filmed for the WGBH (Boston) Math Library Project.
- Over 20 SJVMP teachers have written Internet-based mathematics lessons linked to the state mathematics content standards for SCORE-Math (http://score.kings.k12.ca.us/lessons.html) and/or have written mathematics lessons to accompany instructional television (ITV) programs. Teachers involved in writing the ITV lessons provided training for other teachers at the KQED (San Francisco-based) National Math, Science, and Technology Conference in 1994.
- Three SJVMP teachers were selected as mathematics resource teachers, coordinators, and writers for a statewide online high school program, CyberHigh.
- Over 50 teachers were trained in the use of replacement unit curricula and delivered regional inservices.
- Ten to twelve SJVMP teachers serve as part-time instructors each semester for mathematics or mathematics methods courses for preservice teachers at area colleges and universities.
- Over 200 of the SJVMP participants have served as school site mentor teachers (math specialization), mathematics workshop

leaders, and/or presenters as local and regional mathematics conferences.

- Three SJVMP staff members were recently selected to be the Fresno and Tulare County Mathematics Coordinators and the regional coordinator of the California Technology Assistance Project.
- In the past several years, members of the SJVMP have served in a number of leadership roles at the state level, including service on the California Framework Commission, statewide mathematics assessment and accreditation panels, and state mathematics curriculum advisory panels.

Postscript

The above profile of the San Joaquin Valley Mathematics Project provides but one example of the effectiveness of the California Mathematics Project model in developing K-12 mathematics teacher leaders. Participants enthusiastically credit the Project with having prepared them for and supported them in their leadership roles. For many years, the vision of the CMP, site directors, staff, and teachers was consistent with the state's vision of progressive educational reform. In 1986, then-State Superintendent of Public Instruction Bill Honig observed, "There is a growing spirit of optimism and a can-do attitude among educators that I think bodes well for the future of the state and the future of the country." For members of the CMP community, this spirit of optimism has been sorely tested recently, affecting the community's strength, effectiveness, productivity, and morale.

In recent years, California has experienced a powerful, effective backlash against the NCTM *Standards*, the reform-oriented *Mathematics Framework* (CDE, 1992), and reform-oriented mathematics curricula (e.g., *MathLand, Connected Mathematics*, and the *Interactive Mathematics Program*) by individuals and groups with important political ties. For reviews and commentary, see Becker and Jacob (1998), Carlos and Kirst (1997), Jackson (1997a, 1997b), and Jacob and Akers (1999). These writers document how policy decisions regarding the *Mathematics Framework* (1999), *Mathematics Content Standards* (http://www.cde.ca.gov/board/mcs_intro.html), textbooks, and assessment were taken out of the hands of teacher leaders and mathematics educators and placed primarily in the hands of selected mathematicians and members of the State Board of Education (SBE). The SBE recently approved a new *Mathematics Framework* (http://www.cde.ca.gov/cilbranch/eltdiv/mathfw.htm), with a more traditional focus and containing rigorous, skills-based content standards on which a new assessment system, STAR (http://star.cde.ca.gov/) is based. A recent mathematics textbook adoption (AB 2519) resulted in the approval of a limited number of traditional books that were closely aligned with the state standards (http://www.cde.ca.gov/cilbranch/eltdiv/ab2519math.htm) but considerably different from recent textbook analyses/recommendations from national groups such as the American Association for the Advancement of Science (http://project2061.aaas.org/matheval/part1.htm).

In early 1998, Governor Pete Wilson removed the California Subject Matter Projects from a draft version of his budget. Negotiations restored the projects, but under new legislation – AB 1734 (Mazzoni). This bill requires the CSMPs to use the state content standards as the principal reference point for CSMP-sponsored professional development activities. Mathematics content is to be the primary focus of California Mathematics Project institutes and follow-ups. CMP sites must form partnerships with low-achieving schools and provide mathematics instruction for these schools' teachers. The test performance of students in the partnership schools is to be monitored and used as one of each project site's accountability measures.

Following the introduction of AB 1734, CMP sites were required to reconceptualize their programs and submit proposals in accordance with the new legislation. Only 11 sites out of the 17 that had been in operation for nearly a decade received funding for 1998-1999. Fifteen of the 19 sites that submitted proposals in 1999 (13 of the original sites) were funded for 1999-2000. In late 1998, the entire staff of the Executive Office of the CMP resigned, and as of August, 1999, a permanent Executive Director had not yet been named.

The next few years will be a time of reflection, reconceptualization, and rebuilding for the California Mathematics Project. The former CMP model embraced and built upon the tenets of a progressive mathematics reform movement, which was supported by and consistent with existing statewide policies for curriculum, instruction, and assessment outlined in the opening pages of this chapter. Teacher leaders (and teacher educators) were actively involved in curriculum development and assessment; they were part of the decision-making process, an important element of teacher leadership.

The new CSMP model, under AB 1734, is consistent with the current statewide focus—one that does not embrace the tenets of the reform movement, but instead focuses on a more traditional skill development/assessment model where teachers' professional involvement and decision-making opportunities are more restricted. The former CMP model was highly successful in developing a thriving statewide cadre of enthusiastic, knowledgeable, professionally-involved teacher leaders for K-12 mathematics. The CMP also provided a productive professional network for university mathematicians and mathematics educators who were involved as Project Directors and Principal Investigators. The capacity of the "new CMP" to recapture the momentum and success enjoyed by the "old CMP" is difficult to predict. The final story of the California Mathematics Project will be a revealing study of how two contrasting models compare in their effectiveness in developing and sustaining K-12 mathematics teacher leaders.

References

Bartels, D. M. (1990, August). *Issue paper II for the subject matter professional development projects: What is level IV and how do we get there?* Oakland, CA: University of California.

Becker, J.P., & Jacob, B. (June, 1998). 'Math war' developments in the United States (California). *ICMI Bulletin,* no. 44, 16-25.

Bohlin, C.F. (1999). *Developing teacher leaders for the next millennium: Proposal for the San Joaquin Valley Mathematics Project 1999-2002.*

Bohlin, R. M. (1996*). Evaluation Report for the San Joaquin Valley Mathematics Project.*

Burns, M. (1998). *Math: Facing an American phobia.* Math Solutions Publications.

California Department of Education (1992). *Mathematics framework for California public schools.* Sacramento: Author.

California Department of Education (1999). *Mathematics framework for California public schools.* Sacramento: Author.

California Mathematics Project (1994). *California Mathematics Project vision statement.* San Diego State University: Author.

California Postsecondary Education Commission. (1986). *Evaluation of the California Subject Matter Projects.* Sacramento, CA: Author.

Carlos, L., & Kirst, M. (1997). *California curriculum policy in the 1990s: "We don't have to be in front to lead."* Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL. (also available at http://www.wested.org/policy/pubs/)

Castle, K., & Aichele, D. B. (1994). Professional development and teacher autonomy. In D. B. Aichele (Ed.), *Professional development for teachers of mathematics* (pp. 1-8). Reston, VA: National Council of Teachers of Mathematics.

Darling-Hammond, L. (1998, November). Using standards to support student success. In *Restructuring Brief #15*. California Professional Development Consortia.

Dehaene, S. (1997). *The number sense. How the mind creates mathematics.* New York: Oxford University Press.

Firestone, W. A., & Pennell, J. R. (Summer, 1997). Designing state-sponsored teacher networks: A comparison of two cases. *American Educational Research Journal, 34* (2), pp. 237-266.

Foundation for Advancements in Science and Education (FASE). (1993). *Good morning Miss Toliver* [video]. (Available from FASE at http://www.fasenet.org)

Franke, M.L., Carpenter, T., Fennema, E., Ansell, E., & Behrend, J. (1998). Understanding teachers' self-sustaining, generative change in the context of professional development. *Teaching and Teacher Education, 14*, 67-80.

Fullen, M., & Hargreaves, A. (1998). Teacher change. In *Teacher change: Improving K-12 mathematics.* [Online: http://change.enc.org/change/01fram/2tchange/cd389/389_009.htm] Eisenhower National Clearinghouse for Mathematics and Science Education.

Gabriele, A.J., Joram, E., Trafton, P., Thiessen, D., Rathmell, E., & Leutzinger, L. (1999, April*). Traveling along the path of mathematics reform: Changes in teachers' sources of efficacy and representations of their students' thinking.* Paper presented at the Annual Meeting of the American Educational Research Association, Montréal, Canada.

Intersegmental Coordinating Council. (1993). *K-12 school reform: Implications and responsibilities for higher education.* Sacramento, CA: Author.

Inverness Research Associates. (1998). *California subject matter projects.* Inverness, CA: Author.

Jackson, A. (1997a). The math wars: California battles it out over mathematics reform (Part I). *Notices of the AMS. 44* (6), 695-702.

Jackson, A. (1997b). The math wars: California battles it out over mathematics reform (Part II). *Notices of the AMS. 44* (7), 817-823.

Jacob, B., & Akers, J. (1999, April). *"Research based" mathematics education policy: The case of California 1995-1998.* Paper presented at the Research Presession of the National Council of Teachers of Mathematics Annual Meeting, San Francisco, CA.

Little, J.W. (1988). Assessing the prospects for teacher leadership. In A. Lieberman. (Ed.). *Building a professional culture in schools.* p. 78-106. New York: Teacher College Press.

Little, J.W. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis, 15* (2), pp. 129-151.

Little, J.W., Gerritz, W.H., Stern, D.S., Guthrie, J., Kirst, M.W., & Marsh, D.D. (1987). *Staff development in California: Public and personal investment, program patterns, and policy choices.* San Francisco, CA: Far West Laboratory for Educational Research and Development.

Loucks-Horsley, S., Hewson, P.W., Love, N., & Stiles, K.E. (1998). *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA: Corwin Press, Inc.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the state. *School Science and Mathematics, 99*(5), pp. 258-271.

Medina, K., & St. John, M. (1997, June). *The nature of teacher leadership: Lessons learned from the California Subject Matter Projects.* Inverness, California: Inverness Research Associates.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: U.S. Government Printing Office.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics.* Reston, VA: Author.

National Research Council. (1989). *Everybody counts: A report to the nation on the future of mathematics education.* Washington, DC: National Academy Press.

Scholastic, Inc. (1994). *Mathematics: What are you teaching my child?* [video]. (Available from Creative Publications: www.creativepublications.com)

Sharp, P.A. (1993). *Sharing your good ideas: A workshop facilitator's handbook.* Portsmouth, NH: Heinemann.

Stokes, L., Hirabayashi, J., & St. John, M. (1998, September). *Contributions of the California subject matter projects to teachers' classroom practice and leadership: Results from a survey of CSMP teacher leaders.* Inverness, CA: Inverness Research Associates.

University of California Office of the President (UCOP). (1994, Spring). *The California subject matter projects: Professional development by and for teachers.* Oakland, CA: Author.

9

The Emergence of Teacher Leaders Through Professional Development

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The PUMP Algebra Project was a systemic effort in a mid-size urban city focusing on professional development of middle school mathematics teachers, and having a long-term goal of enabling more minority students to be algebra-ready by the end of 8th grade. The development of teacher leaders was not a targeted focus of the Project; it was a major unanticipated benefit of the Project. Through summer content and pedagogical courses, academic year seminars, and classroom-level support, teachers began to provide leadership in their buildings with regard to four PUMP classroom strategies: emphasizing that mathematics is for all, engaging students in worthwhile mathematical tasks, enhancing students' mathematical discourse, and involving students in collaborative mathematical activities. These teacher leaders also played key roles in their district in revamping their lowest level high school mathematics courses, integrating technology into instruction, and adopting broader approaches to assessment. PUMP teachers also emerged as leaders in the Urban League-sponsored after-school and summer algebra programs for middle school students, a big brother / sister after-school mathematics mentoring program, the collaborative design of an applied mathematics student module with Caterpillar engineers, and the creation of an affiliate mathematics education group of the National Council of Teachers of Mathematics.

In response to the need for improved opportunities for student learning of mathematics at all levels (National Academy of Sciences, 1990; Beaton, Mullis, Martine, Gonzalez, Kelly, & Smith, 1996), the mathematics education community has called for significant changes in mathematics teaching and learning (National Council of Teachers of Mathematics [NCTM], 1991, 1998). Classroom teachers are central to this change process and play a critical role in enacting new visions of teaching and learning mathematics (Ferrini-Mundy, 1998). Thus, the professional development of teachers of mathematics has received unparalleled attention in recent years (Aichele & Coxford, 1994; Friel & Bright, 1997). A critical part of this process of teacher enhancement is the development of teacher leaders.

Teacher leaders play key roles in initiating and supporting change. These roles include: planning and initiating professional development for other teachers, collaborating in the writing and development of curriculum, addressing instructional problems with administrators and community members; and facilitating networks of communication (Friel & Bright, 1997; Loucks-Horsley, Hewson, Love & Stiles, 1998). The contributions of teacher leaders to the long-term success of teacher enhancement projects have been widely recognized in the literature (Friel & Bright, 1997; Fullan, 1993; Loucks-Horsley, Hewson, Love, & Stiles, 1998).

There are two approaches to developing teacher leaders. One approach involves identifying exemplary teachers as potential leaders and engaging them in programs designed to prepare them to assume leadership roles. While this approach has merit (Friel & Bright, 1997), Gregg (1997) observes that the early identification of teacher leaders may not result in the selection of teachers with the greatest potential for leadership, as not every good teacher of children is necessarily a good leader of adults. A second approach to the identification of teacher leaders is one that promotes the emergence of leaders through teachers' participation in general professional development programs. This latter approach to leadership is the one that evolved during the PUMP Algebra Project and is the focus of this chapter.

The PUMP Algebra Project: Fostering the Emergence of Teacher Leaders

The PUMP (Peoria Urban Mathematics Plan for) Algebra Project, funded by the National Science Foundation and directed by faculty from the Mathematics Department of Illinois State University, is an example of a teacher enhancement effort that evolved in the emergence of teacher leaders. The development of teacher leaders was not a targeted focus of the PUMP Project. However, we did recognize that if the Project was to have sustained impact on the quality of mathematics instruction and learning in the school district beyond the period of funding, teacher participants would need to remain committed to Project philosophy and continue to support curricular and pedagogical reforms when the Project was no longer active.

The fact that this continuing commitment to the philosophy of the Project has occurred can be attributed to the emergence of teacher leaders among the participants in our project. In retrospect, we find it possible to analyze the elements of the Project to highlight instances of this emergence and target specific features that fostered the development of teacher leaders. As a precursor to examining this emergence, we provide a summary of major Project activities and set this in the framework of the Loucks-Horsley et al. (1998) strategies for professional learning.

The PUMP Algebra Project and Goals

A systemic effort in a mid-size urban city, the PUMP Algebra Project was designed to enable more minority students to be algebra-ready by the end of eighth grade. The Project was a collaborative effort involving district administrators and 48 teachers representing each of the district's 14 middle schools and 4 high schools; faculty and graduate students from the University; and significant involvement and support from community and business groups. The major goals of the PUMP Algebra Project were:

- To provide teachers with enhanced content, pedagogical, and professional knowledge through intensive summer sessions and follow-up academic year seminars;
- To encourage classroom-based implementation of new knowledge and practice through on-site staff support; and
- To positively impact student achievement and thereby increased entry into the algebra pipeline.

Believing that improvement in mathematics achievement begins in the classroom with teachers, the main thrust of the Project was a strong professional development program for teachers. An unanticipated outcome of this strong professional development program was the emergence of teacher leaders.

The Components of the Professional Development Program

In order to effect worthwhile and enduring change in mathematics teaching that increased student achievement and entry into the algebra track, the PUMP Project focused on the enhancement of teachers' knowledge through participation in activities that served to influence their beliefs about, and practices in, mathematics teaching and learning.

The major components of this professional development program included summer courses, academic year seminars, on-site classroom support for teachers, and community/business involvement. These four components of the PUMP Project professional development program are described below, followed by an analysis of how they relate to proven strategies for teacher learning (Loucks-Horsley et al., 1998).

Component 1: Summer Courses. Three intensive summer sessions involved teachers in *doing* mathematics and reflecting on mathematics teaching and learning. In essence, these summers engaged teachers in reflective inquiry centered on key mathematical ideas of the middle school curriculum. Over the three years, the summer mathematics courses addressed the content of rational numbers and proportional reasoning, algebraic thinking, geometry, probability and statistics. Each summer, specific lessons were also planned to familiarize teachers with graphing calculators and ways to effectively integrate their use in middle school mathematics instruction.

Four PUMP classroom strategies (Figure 1) were modeled during the summer sessions to help teachers operationalize the reflective inquiry approach. We consistently emphasized that all teachers should be engaged in completing rich, meaningful mathematical tasks. The expectation was that teachers would share their different solution approaches, explain and justify their reasoning. Teachers were often expected to work collaboratively with colleagues and this resulted in opportunities for teachers to assume leadership roles.

PUMP Classroom Strategies

- Emphasize that mathematics is for all students.
- Engage students in worthwhile mathematical tasks.
- Enhance levels of student discourse about mathematical ideas.
- Involve students in collaborative mathematical activities.

Figure 1. PUMP Classroom Strategies

Replacement units from the Connected Mathematics Project (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1997, 1998) were used as the texts for these summer courses and provided a springboard for teachers to study new content, to revisit familiar content from a new perspective, and to analyze new approaches to teaching these topics. Teachers were given opportunities in the summer to rethink and reorganize their mathematics program to incorporate enhanced forms of instruction. Part of each summer's assignment was to collaboratively develop and share instructional plans that either outlined specific units of study or organized the entire year's scope and sequence. These experiences strategically positioned teachers to provide leadership in their buildings for the coming year.

Component 2: Academic Year Seminars. During each academic year teachers attended six half-day seminars. For these seminars teachers met in grade-level clusters (5-6 and 7-8) to:

- improve articulation across grade levels;
- facilitate grade-level sharing; and
- provide a broader base for analyzing and implementing instructional strategies in mathematics.

During the first year, seminar discussions were based on the four PUMP classroom strategies shown in Figure 1. Each seminar focused on one of the classroom strategies and utilized problem-centered tasks, research findings, or a video as the context for discussion. Teachers were engaged in tasks such as the following:

- Reflecting briefly in writing on how they used one of the PUMP strategies in their classroom since the last seminar;
- Sharing samples of student work that reflected the levels of thinking and strategies used by students in their classrooms; and
- "Opening up" a traditional textbook lesson by restructuring it to include problem tasks that allowed for multiple solutions or encouraged different solution approaches.

At the conclusion of each seminar, teachers were given a specific task related to one of the PUMP strategies to carry out in their classroom before the next seminar. In a number of cases these assignments provided a catalyst for some teachers to be innovative in their classrooms and, in essence, to show leadership in implementing the PUMP pedagogy.

Seminars in the second and third years adopted a similar format to that developed during the first year. However, in year 2, seminars focused on proportional reasoning, technology, and issues surrounding standardized testing. As part of an effort to disseminate Project ideas more broadly, teachers also participated in two seminars with other teachers from their buildings who were not actively involved in the PUMP Project. These sessions provided another opportunity for PUMP teachers to demonstrate leadership among their peers.

During the third and final year, teachers shared the responsibility of leading five seminars which again emphasized the PUMP classroom strategies. One of these seminars included non-PUMP teachers that had participated in PUMP seminars during the previous year. A key element of all these seminars was the initiatives demonstrated by teachers in better aligning their curriculum and instructional practice with the vision of the PUMP Project. While the third-year seminars were not initially intended to promote teacher leaders, it was clear to both the Project staff and the teachers themselves that leaders had emerged. Moreover, the leadership of these key people resulted in several powerful outcomes. For example, the mathematics departments in all four high schools came to consensus on revamping their lowest-level mathematics courses using new standards-based middle school curriculum materials.

Component 3: Classroom-Level Support. Throughout the school year, four to six project staff members spent one day a week in PUMP classrooms. During these visits, staff were available for a variety of support activities including: teaching a demonstration lesson or co-teaching a lesson (with a follow-up debriefing session), observing and providing feedback to the teacher, or serving as consultant on specific curriculum or instructional issues. Each year some teachers were targeted for weekly visits; all others were visited at least twice during the year. These visits provided further opportunity for project staff to identify evidence of teacher leadership within their own buildings.

Component 4: Community and Business Collaboration

The PUMP project had significant community and business support. The Urban League sponsored a diversity workshop for teachers, established an after-school tutor program for middle school students, established a PUMP Algebra Club that met after school once each week, and instituted a six-week summer PUMP Algebra program for middle school students. Both the Algebra Club and the algebra summer program had separate grade 5-6 and grade 7-8 components. The after-school tutor program involved college interns from Caterpillar, Inc., college students from local universities, parents, and other adult volunteers as tutors. All activities were planned and implemented under the leadership of PUMP teachers who generated the curriculum programs and provided mentoring for the various tutors.

The Chamber of Commerce sponsored Big Brother/Sister type mentoring in mathematics at the middle schools before and after school and during lunch periods. As part of their Adopt-a-School program, they also provided incentives for students who showed ongoing improvement in mathematics achievement. Once again, a number of PUMP teachers took the lead in coordinating and implementing these programs.

A significant number of businesses collaborated in a fundraising campaign to purchase graphics calculators for all of the district's middle schools. In particular, Caterpillar and Central Illinois Light Company provided direction for this effort and continued, throughout the project, to serve as resources. Some of the PUMP teachers with a strong interest in technology assumed leadership roles in providing graphics calculator workshops for teachers across the district. In essence, the Project had the effect of galvanizing PUMP teachers to take initiatives beyond the scope of the Project.

Within the same timeframe, engineers from Caterpillar worked with lead PUMP teachers to design a wheel-in-motion unit that was subsequently taught in many of the district's middle school classrooms by the engineers in collaboration with PUMP teachers. Caterpillar also sponsored a PUMP Teacher Appreciation Day at corporate headquarters which included teaming and leadership activities.

Relationship Between PUMP Project Activities and Strategies for Professional Learning

In designing and implementing the PUMP project, we strove to incorporate proven strategies for teacher learning. In fact, the strategies we enlisted are among those recently described by Loucks-Horsley et al. (1998): (a) immersion in inquiry, (b) curriculum replacement units, (c) curriculum development and adaptation, (d) workshops, institutes, courses, and seminars; and (e) examining student work and student thinking (see Table 1).

Table 1. Strategies for Professional Mathematics

- † Immersion in inquiry
- Curriculum implementation
- † Curriculum replacement units
- Action research
- Case discussions
- Study groups
- Coaching and mentoring
- Professional networks
- Immersion in the world of mathematicians
- Curriculum development and adaptation
- † Workshops, institutes, courses, and seminars
- † Examining student work and student thinking
- Partnerships with mathematicians in business, industry, and universities
- Developing professional developers

*Loucks-Horsley, Hewson, Love, & Stiles (1998)
†Relevant to the PUMP Algebra Project's emergent leader experience

Immersion in Inquiry

The major approach to mathematics learning during the summer courses was immersion in inquiry. An inquiry approach to mathematics learning involves engagement in rich problem tasks that invite different solutions or different solution approaches. During the summer sessions, we provided teachers with repeated opportunities to grapple with complex mathematical problem tasks, usually in collaboration with teacher colleagues. Our expectation was that teachers would explore and share their different solutions and reasoning, and benefit from ideas shared by others.

Our overriding goal was consistent with the benefits Loucks-Horsley et al. (1998) identified for immersion in inquiry: (1) to increase teachers' mathematical understanding in content areas central to school mathematics instruction; and (2) to broaden teachers' perspectives and understanding of their own process of learning through investigation. PUMP staff felt that, to be effective in promoting inquiry during mathematics instruction, teachers must be mathematically knowledgeable, fully understand and be committed to the inquiry process. We believed it was important to challenge teachers at their own level of mathematical understanding and allow them to both experience and reflect on the same practices that we were encouraging them to carry out with their students.

Curriculum Replacement Units

Loucks-Horsley et al. (1998) highlighted the potential that well-designed replacement units have for shifting teachers' thinking and beliefs about teaching and learning. Our belief in this potential for improving mathematics instruction lay at the heart of our decision to use selected units from the materials (Lappan et al., 1997, 1998) during the PUMP Project's summer sessions. Although we modified some activities for adult learners, we also provided time for teachers to try student activities first-hand, thus enabling them to better understand the purpose and philosophy of the materials and the way that students approach such activities. Our intent was that teachers would incorporate some of the Connected Mathematics modules as replacement units in their classrooms during the school year, and that doing so would stimulate a larger-scale change in their instructional practice.

Following each summer session more and more teachers began to use some of the *Connected Mathematics* lessons or even entire replacement units in their classrooms. These teachers were encouraged to take this action both by having experienced the units themselves and by peers who had already taken the initiative in using the replacement units. Loucks-Horsley et al. (1998) suggested that replacement units allow teachers the chance to sample new teaching strategies without completely adopting a new mathematics curriculum. According to Loucks-Horsley et al., teachers also need time to reflect and "debrief" on new curriculum experiences; they need opportunity to interact both with grade-level colleagues and with supportive consultants during the period a replacement unit is first made part of classroom instruction. The real forum for professional learning in the use of replacement units is rooted in on-going opportunities for teachers to discuss what is happening, to share problems encountered, and to receive support and guidance.

As PUMP teachers tried ideas in a replacement unit with their students and interacted with their peers who were already using these units, they reported that they were challenged to rethink their teaching practice. Seminar sharing, especially by lead teachers, provided needed support for orchestrating effective ways to implement replacement units in classroom instruction.

Curriculum Development and Adaptation

When describing the benefits of curriculum development and adaptation as a professional learning strategy, Loucks-Horsley et al. (1998) point out that this activity pulls teachers away from the isolation of their individual classrooms. They also note that curriculum development and adaptation provides them with rare, needed opportunities to interact professionally with colleagues or other experts in the field.

The capstone experience of each of the summer sessions in the PUMP Algebra Project was the sharing of a curriculum unit directly tied to the topic(s) of the summer session or a year-long curriculum plan that set a timeframe for and highlighted activities associated with the mathematics content of a summer's session. The annual curriculum development/adaptation assignment of the PUMP Project's summer sessions proved valuable for teachers for this very reason: it gave them the opportunity to collaborate repeatedly with their colleagues and with professional mathematics educators. Our hope was that, as teachers collaborated to rethink their instructional goals in relation to specific mathematics concepts, skills, and attitudes their students needed to acquire, they would strengthen their own content and pedagogical knowledge.

Curricular development and adaptation continued to be emphasized throughout the academic-year seminars but focused on making modifications of specific mathematics lessons. This development and adaptation became very practical as teachers tried and refined new or modified lessons with their students. The basis for lesson modification was primarily the four PUMP classroom strategies (Figure 1); the forum for lesson modification was collaborative planning between seminar sessions and collegial sharing during seminars. Regular interaction with de facto teacher leaders in developing or adapting curriculum for improved classroom instruction became, as Loucks-Horsley et al. (1998) indicated, one of the strongest professional learning features of this experience.

Workshops, Institutes, Courses, and Seminars

The most obvious of the Loucks-Horsley et al. (1998) strategies utilized during the three sequential summers of our PUMP Project program was our use of courses to provide teachers with enhanced content, pedagogical, and professional knowledge. The summer schedules provided teachers with time away from the classroom to grapple with mathematical problems in ways they had not previously thought about or experienced. While focused on the enhancement of content knowledge, however, these courses also engaged teachers in what Loucks-Horsley et al. (1998) refer to as a "taking action" (p. 90) stage--in which they applied newly-learned mathematical ideas and ways of learning to their own classroom situations.

As follow-up to summer work, the PUMP Project's regular seminar meetings with their focus on improved pedagogy created opportunities for teachers to learn more about reform recommendations for school mathematics. They also provided a forum for teachers to share their experiences and learn from colleagues. Both the summer and seminar activities served as a catalyst for teachers to take leadership in relation to issues associated with mathematics content, mathematics pedagogy, and technology integration. Each seminar offered new challenges to rethink the teaching and learning of mathematics.

Examining Student Work and Student Thinking

As part of each seminar, targeted teachers shared lessons they planned in relation to one of the four PUMP Classroom Strategies (Figure 1). During this sharing, teachers exhibited samples of student work from a lesson and engaged their colleagues in examining different strategies students used and different levels of thinking revealed by those strategies.

This activity served three purposes: (a) it held teachers accountable for trying new approaches to mathematics instruction; (b) it gave teachers precious time for reflection; and (c) it enabled teachers to observe and benefit from the modeling and sharing of recognized teacher leaders. What Loucks-Horsley et al. (1998) suggested might happen did in fact occur among many PUMP Project teachers: the practice of carefully reflecting on students' reasoning caused teachers to "develop for themselves the ability to understand the content [that their] students are struggling with ...[in order to determine] ways that they . . . can help" (p. 125). That is, by thoughtfully and regularly examining student work and thinking, teachers grew in their own understanding of the mathematics and obtained information that was important for on-going, instructional decision-making (Swafford & Thornton, in press).

Aspects of the PUMP Project that Fostered the Emergence of Teacher Leaders

In designing and implementing the PUMP professional development program, we strove to incorporate proven strategies for teacher learning. In retrospect the strategies we utilized, aptly characterized by five of the Loucks-Horsley et al. (1998) strategies for professional learning, became a forum of opportunity that fostered the emergence of teacher leaders. In reflecting on the PUMP Project, we are convinced that these strategies nurtured the emergence of teacher leaders by:

- engendering increased personal confidence in mathematics content as demonstrated in teacher modeling and sharing of problem solutions; (Components 1 and 2: Summer courses and academic year seminars);
- building teacher expertise in relation to reform-based approaches to mathematics instruction as revealed in the teachers' development of pedagogical ideas, instructional plans, and classroom implementations (Components 1, 2 and 3: Summer courses, academic year seminars, and classroom-level support); and
- providing repeated opportunities for teachers to assume responsibilities for team-building and sharing of mathematical, pedagogical, and technological ideas as evidenced by teacher initiatives during PUMP Project activities, in their own classrooms and after-school programs, and in their work with business and community groups(All four components).

Indicators of emerging teacher leadership at different points in the program have been highlighted throughout our discussion of the four Project components and in relating these components to strategies for professional learning (Loucks-Horsley, et al., 1998). While a number of key participants demonstrated leadership in many settings and roles, an interesting feature of this Project was the change in leadership as teachers were involved in different aspects of the Project.

Teachers also assumed leadership at different levels. Some exhibited leadership only with their own cohort of grade-level teachers; others demonstrated more pervasive leadership roles within their own schools or at the district level. This broader leadership, for example, was evidenced in PUMP participants giving presentations at district, state, and national mathematics teacher conferences and in their initiation of a local affiliate mathematics teacher group.

This new affiliate group of the National Council of Teachers of Mathematics was formed by PUMP teachers near the end of the Project because they wanted to keep the momentum of the Project alive. The first officers of this organization, the Heart of Illinois Council of Teachers of Mathematics, were all PUMP teachers. At the time of writing this chapter, the organization included 80 members and had just elected its second president and its second president-elect. Both of these newly elected officers are PUMP Project participants. For Project staff, the formation of this organization has been one of the highlights in the emergence of teacher leaders because it provides an on-going mechanism for maintaining and enhancing the spirit of the PUMP Project.

Concluding Comments

The PUMP Project not only enhanced the professional development of teachers, it acted as a catalyst for fostering the emergence of teacher leaders. The emergence of these teacher leaders has been an unanticipated benefit--one that may well have more long-lasting effects than other components of the Project .

References

Aichele, D. B. & Coxford, A. F. (Eds.). (1994). *Professional development for teachers of mathematics* (1994 Yearbook). Reston, VA: National Council of Teachers of Mathematics.

Beaton, A. E., Mullis, I. V. V., Martine, M. O., Gonzalez, E. J., Kelly, D. L., & Smith, T. A. (1996). *Mathematics achievement in the middle school years: IEA'S Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

Ferrini-Mundy, J. (1998). Reform efforts in mathematics education: Reckoning with the realities. In S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work,* (pp. 113-132). New York: University Press of America.

Friel, S. N., & Bright, G. W. (Eds.) (1997). *Reflecting on our work: NSF teacher enhancement in K-6 mathematics.* New York: University Press of America.

Gregg, L. (1997). Mathematics and Science Enhancement (MASE) Project, in S. N. Friel & G. W. Bright (Eds.), *Reflecting on our work: NSF teacher enhancement in K-6 mathematics* (pp. 215-222). New York: University Press of America.

Lappan, G., Fey, J. T., Fitzgerald, W. M., Friel, S. N., and Phillips, E. D. (1998). *Connected mathematics* (Grade 6 and 8 units). Palo Alto, CA: Dale Seymour Publications.

Lappan, G., Fey, J. T., Fitzgerald, W. M., Friel, S. N., and Phillips, E. D. (1997). *Connected Mathematics* (Grade 7 units). Palo Alto, CA: Dale

Seymour Publications.

Loucks-Horsley, S., Hewson, P. W., Love, N, & Stiles, K. E. (1998). *Designing professional development for teachers of mathematics.* Thousand Oaks, CA: Corwin Press.

National Academy of Sciences. (1990). *Making mathematics work for minorities.* Washington, DC: The Academy.

National Council of Teachers of Mathematics. (1998). *Principles and standards for school mathematics: Discussion draft.* Reston, VA: The Council.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics* Reston, VA: The Council.

Swafford, J. O. & Thornton, C. A. (in press). The PUMP Algebra Project. In J. Killion (Ed.), *Results-based staff development for the middle grades.*

10 Developing Chemistry and Mathematics Teacher Leaders in Israel

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The implementation of new standards in science and mathematics education necessitates an intensive and comprehensive professional development of science and mathematics teachers. Israel, which currently is in the process of reforming school science and mathematics, constructed continuous lifelong framework for such professional development. This framework includes the development of science and mathematics teacher leaders. This chapter presents a detailed description of two examples of such leadership preparation in chemistry and mathematics teaching conducted at the Department of Science Teaching in the Weizmann Institute of Science. There are similarities in the structure of the two courses. However, the content and activities were designed to attain the specific nature and goals of each of these areas in general, and the aims and objectives of the curriculum developers in particular.

New standards in science and mathematics education are being advocated, standards which reflect the current vision of the content, classroom environments, teaching methods and support necessary to provide high quality science and mathematics education for all students (National Council of Teachers of Mathematics, 1989, 1991; National Research Council, 1996). The standards portray a direction for further reform in science and mathematics education.

The 1960s and the 1970s were the golden age of reform in curriculum development in science and mathematics. In contrast, the reform of the 1990s is characterized by both the development of new curricula and attention to teacher learning and the professionalization of science and mathematics teachers. This new focus is based on a lesson learned from the previous intensive and comprehensive efforts in curriculum development, where it became apparent that a good curriculum is necessary, but by no means sufficient, since teachers rarely use curriculum materials as intended by their developers (Romberg & Pitman, 1990).

To illustrate this, we present an episode observed in an algebra lesson (Robinson, 1993). The lesson centered on the topic of equivalent algebraic expressions. The textbook's presentation of this topic included a task that was planned to provide meaning for the all-too-common meaningless requests in algebra lessons to simplify algebraic expressions. The students were to substitute the same fraction in two equivalent expressions, one "complex" and the other "simple." Since calculations in the former case were more complicated than in the latter, the textbook writer anticipated that students would realize that simplifying expressions is worthwhile, and would thus be motivated to learn to simplify. The class teacher knew the mathematics required and was familiar with the curriculum materials.

Following the textbook's suggestion, the teacher wrote on the board two expressions, one simple and the other complex: 4a+3 and $\frac{3a+6+5a}{2}$ but forgot to mention that the two expressions are equivalent. Then he asked the students to substitute a fraction in both expressions:

T: Substitute a = 1/2 .

S_1: You get the same result.

Noticing that he forgot to mention that the two expressions were equivalent, the teacher focused on this now. But instead of just stating the fact, as suggested in the textbook, he asked:

T: Are the algebraic expressions equivalent?

At this stage in their study, the students could not answer this question (this is why it was suggested in the textbook that they be told). Consequently their reactions deviated from the original plan, and they initiated a debate of this issue among themselves:

S_2: No, because we substituted only one number.

S_1: Yes.

S_3: It is impossible to know. We need all the numbers.

S_4: One example is not enough.

Clearly, the students were not engaged in the task as had been planned; however, they were engaged, on their own initiative, in a genuine and important mathematical discussion. The teacher ignored the students' discussion completely, and adhered to the original plan:

> T: We can conclude--it is difficult to substitute numbers in a complicated expression and therefore we should find a simpler equivalent expression.

While the substitution of a=1/2 in the two given expressions might lead naturally to the conclusion that "we should find a simpler equivalent expression" (as planned by the textbook writer), this was, by no means, the conclusion appropriate to the discussion that took place in that classroom at that specific moment. What students may easily learn from such experiences is that their mathematical thinking is not valued, or that mathematics does not necessarily make sense. Rather what is valued is "what the teacher has in mind" or that the teacher is the authority for determining the correctness of answers.

The above episode illustrates, simply and clearly, the critical role that the teacher has in determining the ways in which science and mathematics are taught and learned in schools, a role, which no curriculum by itself can fulfill. Such a role involves setting teaching goals and creating classroom environments in which these goals are pursued, classrooms in which students encounter, develop, and use scientific and mathematical ideas and skills in the context of genuine problems and situations, and where the teacher chooses appropriate ways to represent the subject matter, asks questions, suggests activities and guides discussions.

Past experiences suggest that knowledge of the subject matter, even at an advanced level, is not enough to equip a teacher to fulfill such a role, nor is acquaintance with ready-made curriculum materials. The above problematic teaching episode occurred in spite of the teacher's adequate mathematical knowledge and his familiarity with the curriculum materials. Teaching in the classroom is much more complicated than a straightforward implementation of a curriculum. It involves attention to classroom discourse, overt and covert messages conveyed when asking students questions, and the conduct of discussions. Consequently, in addition to content and curriculum knowledge, the teacher needs quite sophisticated knowledge about science or mathematics teaching.

Traditional ways of conducting preservice and inservice education and professional development have not been adequate (e.g., Bell & Gilbert, 1997; Loucks-Horsley, Hewson, Love, & Stiles, 1998). The main goal of this chapter is to describe an innovative framework developed in Israel which aims at reforming the professional development of science and mathematics teachers. It focuses on the development of teacher leaders as a vehicle for providing large-scale, long-term, and dynamic inservice professional development. This framework is a part of a more comprehensive reform currently in progress in Israel in science, technology and mathematics education.

The Israeli Context

Israel has a centralized education system. Thus, the syllabi and educational projects, as well as support for teacher professional development, are conducted and regulated by the Ministry of Education, Culture, and Sport. Since the mid 1960s the Ministry has provided for a long term and dynamic process of science and mathematics curriculum development conducted mainly in Science Teaching Centers located in several academic institutions in the country. This process of curriculum development has always included implementation accompanied by assessment and evaluation (diagnostic, formative, and summative).

In 1992, the Ministry released the *Tomorrow 98 Report* (Superior Committee on Science, Mathematics and Technology Education in Israel, 1992) on reform in science, technology and mathematics education. The report includes 43 recommendations for new programs, special projects, changes and improvements, both educational and structural, in the area of curriculum development and implementation, pedagogy of science and mathematics teaching, as well as directions and actions to be taken in the professional development of science and mathematics teachers.

The report acknowledges the central role that science and mathematics teachers play in instruction, stating:

> *The best programs and the best-equipped laboratories will not prove themselves without good teachers. In the end, every subject in the education system stands or falls on the quality, qualifications and dedication of its teachers.* (p. 6)

On the basis of the report's recommendations, the Ministry decided to create a setting that would support on-going learning for teachers. A series of regional teacher support and guidance centers were established (mostly located in teacher colleges around the country). These centers offer various types of inservice courses for the science and mathematics teachers in the region; most of them are one day a week (4-8 hours per day) throughout the school year. The establishment of the regional teacher centers reflects the Ministry's acknowledgment of both the need for teachers to learn to teach in new ways, and of the need for life-long professional development for teachers. More specifically these centers' main goals are to:

- Provide for continuous and sustained support for professional development of science and mathematics teachers.
- Provide science and mathematics teachers with opportunities to engage in life-long learning.
- Create an environment of collegiality and collaboration among teachers who teach the same or related subjects, an environment which encourages reflection on their work in the classroom.
- Incorporate the process of change into professional development (some examples include curriculum change and new and varied instructional techniques).

This large-scale professional development framework is supported and guided by national teachers' centers (usually located in academic institutions in which the main curriculum development is conducted). The overriding aim of the national centers is to encourage educational reform by providing a strong framework to support teacher development. They are responsible for the following activities:

- Development of teacher leaders who will initiate, support, conduct and lead professional inservice development.
- Counseling and support for the regional teacher centers and other regional professional development activities for teachers.
- Development and establishment of high standards in the pedagogy of mathematics and science teaching and learning.
- Development of models for effective professional development of mathematics and science teachers.
- Establishment of a clearinghouse for relevant computer assisted instruction, special experiments, and relevant instructional methods and programs and curricula from all over the world.
- Dissemination at the national level of relevant professional information.

In this chapter, we focus on the development of teacher leaders in the national centers. The teacher leaders' role is to promote teacher learning in regional teacher centers or in other regional and local institutes. The following sections describe two different examples of such programs, each tailored to the needs and goals of the subject as seen by those responsible for these programs. One deals with the professional development of chemistry teacher leaders; the other with the professional development of mathematics teacher leaders. Both programs are two years long (450 hours) and are conducted at the National Chemistry and Mathematics Teacher Centers (respectively) in the Department of Science Teaching in the Weizmann Institute of Science.

Professional Development of Chemistry Teacher leaders

Profile of prospective leading chemistry teachers

The course is open to chemistry teachers who are considered to have the potential to become teacher leaders. These teachers share the following characteristics, more specifically they:

- Serve as chemistry coordinators in their respective schools.
- Have at least 10 years experience in teaching high school chemistry (10-12th grade), including experience in preparing students for matriculation examinations.
- Have participated in a number of inservice professional activities.
- Were recommended by regional tutors as creative and open to changes in science education in general and chemistry teaching in particular.

Structure of the course

The philosophy that underlines the course is that, in recent years, there has been a major change in our perception of the content and pedagogy of chemistry teaching and learning. To reform the content and pedagogy of chemistry teaching, there is a need to educate leaders who will eventually serve as agents for change.

It is suggested that in order to become a leader, the chemistry teacher has to undergo a multiple phase development. The development should include the following dimensions: the new scope of high school chemistry (content knowledge), the improvement of the pedagogy of high school chemistry (pedagogical content knowledge), and the knowledge and skills to develop the teacher as a leader who serves as an agent for change. The following discussion is an elaboration of these dimensions.

The New Scope of High School Chemistry (Content Knowledge)

The aim here is to provide the potential teacher leaders with the scientific (chemistry) content that they lack. In recent years, science educators in general and chemistry educators in particular have realized that science is taught not only to prepare students for an academic career in the sciences (in our case, chemistry), but also to become citizens in a society that is highly influenced by scientific advances and the accompanying technological manifestations. Consequently, chemistry should be taught with appropriate emphasis on its relevance to everyday life and its role in industry, technology and society.

This view was the basis for the claim made by Kempa (1983) that future development of teaching and learning material in chemistry should include the following six dimensions:

- Knowledge and information about chemical transformation and processes and associated principles, concepts and theories-including concepts and principles based on recent investigations (i.e., presenting the frontier of the science).
- Chemistry as an inquiry based discipline, which gives rise to new knowledge and insights and allows problems to be solved both in the classroom as well as in the laboratory. While learning chemistry using the inquiry method, students are able to ask questions, plan and conduct investigations, think critically, construct and analyze alternative explanations and communicate scientific arguments (Bybee, 1997).
- Chemistry as an applied science of major economic and technological importance.
- Chemistry as a subject of distinct personal relevance through its everyday application and uses.
- Chemistry as a human and cultural activity, manifesting itself in the growth of ideas, the development of industries and its influence on peoples' life styles.
- Chemistry as a subject of major social and environmental implications.

This new approach emphasizes the application and relevance of chemistry to everyday life, and is expected to increase students' motivation to learn chemistry. This approach to high school chemistry makes great demands on the chemistry teacher, and only intensive professional development procedures can affect and change teachers' knowledge and beliefs regarding the content and scope of high school chemistry.

During the course the potential teacher leaders are exposed to the above dimensions. They are involved in activities which enable them to integrate the chemistry subject matter with information from the literature of how students learn and construct their knowledge, as well as how to anticipate students' learning difficulties.

The Improvement of the Pedagogy of High-School Chemistry (Pedagogical Content Knowledge)

This dimension concentrates on activities aimed at improving the chemistry classroom and laboratory learning environment. The course participants are exposed to a variety of instructional methods and are also provided with situations that give them opportunities to reflect on their work and experiences. It is based on the assumption that to help others to change, they should first affect change in their own classes and schools.

As mentioned before, the present era is characterized not only by new standards in the content of science, but also by the way science is taught; namely, the pedagogy of science teaching. It is suggested that, curriculum materials and instructional strategies should be tailored to the cognitive abilities and aptitudes of different students. The overall objective is to create a learning environment which allows students to interact physically and intellectually with instructional materials through hands–on inquiry oriented activities.

Hofstein and Walberg (1995) and Tobin, Capie, and Bettencourt (1988) presented evidence that instructional techniques in science should be matched with the learners' characteristics and needs in order to maximize the effectiveness of the teaching and learning processes and also to increase student motivation. Hofstein and Kempa (1985), who postulated that some relationships exist between students' motivational traits (characteristics) and their preferences for particular teaching and learning strategies, also provided support for this idea. This was confirmed in a quantitative research study conducted in the United Kingdom by Kempa and Diaz (1990).

Clearly, in practice, it is difficult to respond to each student's needs, but much can be achieved if teachers use a wide repertoire of instructional strategies, instead of limiting themselves to only one or two. To do so, requires not only skills and knowledge in a variety of teaching methods, but also leadership (managerial) competence to implement these methods in schools, regions and the whole education system. This clearly represents a major challenge to professional development for teachers and educators.

During the course, the participants obtain experience in the following instructional techniques:

- Cooperative learning.
- Simulation games and debates (role-playing).
- Educationally effective field trips (e.g., chemical industry).
- Critical reading of articles in newspapers and scientific journals.
- Inquiry type laboratories and other inquiry type assignments.
- Students' personal chemistry based projects.

Varying classroom instruction implies the use of alternative methods for assessing student progress and achievement. Teachers need to be aware of the different modes of assessment. For example, research on achievement in chemistry (Hofstein, Ben-Zvi, Samuel, & Kempa, 1977) and in biology (Tamir, 1972), has clearly shown that achievement using paper and pencil tests is not well correlated with achievement in practical type tests. The course participants learn how to organize a portfolio to obtain a comprehensive and objective picture of their students' achievement and progress.

The Teacher as a Leader: An Agent for Change

On the basis of research on professional development and change in schools, it is clear that leadership is required for professional development experiences to be turned into changes in teaching and learning (Fullan, 1991). The central goal of the course is to develop chemistry teacher leaders who will foster such change in chemistry education. In particular they should be able to:

- Facilitate communication among and cooperation between teachers.
- Initiate school and regional based curriculum development implementation and evaluation.

Thus, the course participants are guided in methods of conveying the ideas discussed in the leadership course to their peers in schools and to workshop participants in the regional centers. The course aims to develop understanding of leadership, including the bases of power and different leadership styles. The course participants are also involved in workshops aimed at developing skills in decision making, building and managing teams, conflict resolution, problem solving, vision building and communicating, and skills for managing diverse types and characteristics of teachers. All these aim specifically at the reform of the content and pedagogy of chemistry teaching.

These abilities are mainly developed through workshops devoted to educating the leading teachers to become developers and disseminators of curriculum materials in chemistry. For example, a course participant who wished to teach a particular topic in a class which was heterogeneous, both in student ability and also in student preferences for a certain learning technique, became a school based curriculum developer. He was encouraged to vary and tailor the learning material to suit the students' characteristics, with the aim of overcoming motivational obstacles as well as cognitive barriers (i.e., misconceptions and other learning difficulties).

In this and other ways, the course participants are provided with the know-how to alternate the curriculum and the assessment, in order to make it more appropriate to their school structure and its students' special needs and characteristics. As appropriate academic knowledge they are exposed to the literature about conceptual change, learning difficulties and other cognitive and affective variables that influence effective learning in science in general and in chemistry in particular. A long-term aim is to obtain an appropriate blend of materials developed by professional curriculum centers with materials developed by teachers.

The 'teacher based' approach to curriculum development used in the leadership course result in the development of many pedagogical ideas and innovative approaches to the present curriculum, which is in its implementation phase. The teacher leaders are involved in the process of matching the chemistry curriculum to the special structure and needs of their schools by working in teams in the course and then working with teams of chemistry teachers in their schools. The leading teachers are guided in the process of managing and building 'team work' in their particular schools with their fellow chemistry teachers. Most of the 'team work' focuses on reducing the school teachers' anxiety towards the introduction of new topics, new instructional methods and new assessment tools with the aim of varying and improving the chemistry classroom learning environment.

During the leadership course, with the help, guidance and support of the course instructors and peers, the participants are given opportunities to reflect on their fieldwork and thus obtain feedback for the purpose of further development of leadership abilities. This is conducted by what is called an 'open platform' for dealing with problems that emerge in their daily work. This platform supports the development of an environment of collegiality, the ability to share ideas, to critically evaluate new ideas, to openly discuss new ideas and reach conclusions and decisions, and to develop skills of working with other teachers.

Professional Development of Mathematics Teacher Leaders

As in chemistry, the role of mathematics teacher leaders and in-service teacher educators becomes especially important at this time of considerable reform in mathematics education. As conceptions of the teacher role are changing, teachers are expected to act as professionals and decision makers. Teacher leaders can enhance reform in school mathematics by joining curriculum developers, researchers in mathematics education, and decision makers in the educational system. Collectively they can play a major role in setting educational policy and goals, and leading and enhancing the professionalization of teachers. However, such a role requires adequate preparation--a preparation which was missing in Israel when the *Tomorrow 98 Report* (1992) was published.

Teacher leaders and educators require not only adequate preparation but also adequate resources. Similar to the need for instructional materials for both children and teachers in the classroom, teacher leaders and educators require materials developed for the purpose of planning learning experiences in teacher education programs or in professional development activities. The *Manor Project*, a major component of the National Mathematics Teacher Center (Superior Committee on Science, Mathematics, and Technology Education, 1992) responds to both these needs. It aims:

- To prepare promising mathematics educators to serve as leaders, guides and support for secondary teachers in the process of changing and improving mathematics teaching.

- To develop resource materials for project participants and other mathematics teacher educators for their work with teachers.

The following sections describe first the preparation program, and then the resource materials.

The Manor Preparation Program

The program emphasizes the following:

- The development of understanding about current views of mathematics teaching and learning (e.g., NCTM, 1989, 1991).
- The development of both leadership and mentoring knowledge and skills as well as methods for working with other teachers.
- The creation of a professional reference group.

The program started in the 1993-1994 school year and is now running for the third time. It extends over two years in an effort to allow sufficient time for the participants to learn, experience, and experiment with the topics and ideas encountered. Further, experience suggests that there is a need for development and growth in the participants' conceptions, beliefs, and dispositions about the nature of mathematics learning and teaching and about teaching teachers. Such change requires time to be effective. After graduation, the participants are invited to participate in a monthly forum.

Selection for the program is based on the following criteria: (a) a first degree either in mathematics or in a mathematics-related field, such as a B. Ed. with a mathematics major or a B. S. in chemistry; (b) experience in mathematics teaching and experience in inservice work with mathematics teachers, at least one of them at grade nine or above; (c) agreement to conduct weekly inservice work with a group of secondary mathematics teachers during the program; (d) reputation as a successful teacher with the potential to become a good teacher leader or teacher educator; and (e) a reasonable spread of participants across the country.

During each school year, the participants meet weekly for six hours with project staff and guest lecturers, and conduct weekly two-hour professional development activities, some explicitly focused on initiating change in mathematics teaching and learning. As an overall assignment for each year, the participants prepare portfolios that document their learning experiences. Participants receive feedback on partial drafts several times throughout the year both from project staff and from their peers in the program.

Detailed description of aspects of curriculum design and the theoretical rationale for the learning opportunities provided by the Manor Program are described in Even (in press-a). Even (in press-b) examines one component of the Manor Program which is designed to encourage integration of academic knowledge with knowledge learned in practice, in order to challenge the participants' existing conceptions and beliefs and promote intellectual restructuring. In the following section, we describe the program's focus on three types of development that seem essential to the teacher leader and teacher educator role: personal, professional, and social.

Adapting Bell and Gilbert's (1994) use of these terms from the context of teacher development to the context of teacher leader and teacher educator development, we take the term 'personal development' to mean an affective development which involves attending to feelings about the change process, being a teacher leader, and mathematics education and teacher education. 'Professional development' involves changing concepts and beliefs about mathematics education and teacher education, and changing teacher education activities. 'Social development' involves working with and relating to other teacher leaders, educators, teachers, principals and superintendents in new ways.

Personal development. An important goal of the personal development aspect of the program is to help participants develop professional sense and confidence. All program participants have already conducted inservice work with secondary teachers in various projects, or have served as mathematics coordinators in their own schools. However, when entering the program, many do not consider themselves teacher leaders or teacher educators. In many cases, they are not sure what this role really entails, and they feel that they do not have the knowledge nor the skills to lead teachers towards learning about mathematics teaching and changing the traditional practice of school mathematics. In an effort to promote the participants' professional self-esteem, we help them expand their knowledge in several fields related to their work (this is described in the next subsection).

Also, in contrast to the usual in-service courses for teachers in Israel, the Manor Program includes an advanced academic component for which the participants receive graduate credit. In addition to encouraging participant commitment and work investment in the long-term program, this component also encourages the development of professional self-esteem. The message, that they are expected to be part of the leadership to improve mathematics teaching in the country, is also emphasized in words and in actions. We approach the participants as professionals, expecting them to take their work in the program and in the field very seriously, and to respect each other's contributions. Most of those who complete the program report that they have made progress in self-confidence, desire for continuous learning and development, and willingness to accept challenging leadership roles (Even, in press-a).

Professional development. With the aim of changing concepts and beliefs about mathematics education and teacher education, the program centers on mathematical, cognitive, curricular, pedagogical, technological, and social aspects of teaching different mathematical topics. Also, the program examines critical educational issues, enhances mathematical knowledge, emphasizes the development of leadership skills and methods for working with teachers. In addition, the program encourages discussion of practical difficulties and dilemmas and focuses on initiating change in school mathematics teaching and learning.

A factor that characterizes many of the learning experiences offered in the program is the connection between theory and practice. Changing concepts and beliefs about mathematics education and teacher education are intertwined with changing teacher education activities. For example, throughout the program the participants conduct weekly two-hour professional development activities based on what they learn in the course. Participants describe and analyze them in writing on a regular basis, to encourage serious reflection. They receive feedback on their reports from program staff as well as an on-going support in preparing the teacher development activities.

Moreover, most of the final year is devoted to learning how to plan, conduct, and evaluate change initiatives. Emphasis is put on connecting what is learned in the more theoretical components of the program with the issue of actual change in school mathematics. Each participant chooses an aspect of school mathematics on which to work with the teachers in school (e.g., building a mathematics room, helping to prevent at-risk high school students from dropping out and not matriculating, developing a program for student projects, using new technologies). Those who choose the same topic form a team coordinated by a staff member or one of the participants.

Each team member works within the framework of the team topic but has autonomy to plan, conduct, and evaluate the project, according to the work conditions, the teachers involved, the student population, and personal preferences. Team members meet to discuss their work, plan activities, consult with one another, share and discuss ideas, support each other, and explore ways of implementing their plans and evaluating the implementation. In addition, several whole-group meetings are devoted to theoretical aspects of initiating change in school mathematics, such as planning change initiatives, the critical role of the teacher in the success of long-term educational change, fundamental barriers to change related to the nature of teaching, and various ways of evaluating change initiatives. To encourage the participants to reflect on their experiences, they are required to submit a detailed report as the main part of the final year's portfolio.

At the end of the program the participants come to realize that change in school mathematics is a slow and complicated process, and better understand what is entailed. They gradually pay more attention to the needs and desires of the teachers with whom they work, and they are able to identify alternative possible actions and make sound choices. The content and the topics of the teacher development activities they conduct also change. Participants become richer in their knowledge and skills as they pay more attention to teacher learning about learning processes and students' conceptions and ways of thinking. Additionally, they examine student assessment seriously and include cooperative analysis of events that the teachers in the group experience. In the conduct of teacher development activities, the participants gradually encourage active participation of the teachers, start to use technological tools, and emphasize the development of teamwork. The program participants' reflective abilities also develop considerably, until they are able to criticize the teacher development activities they themselves conduct and suggest modifications.

Social development. When beginning the initiatives, quite a few of the participants use the common didactic approach of *telling* the teachers with whom they work what to do and how to do it. Later, they learn that it is important for the teachers to have a sense of ownership, and they start to encourage the teachers to participate in the planning, decision making, assignment of roles, setting of time tables, and sharing of responsibilities--key points for successful professional development work with teachers (e.g., Clarke, 1993; Loucks-Horsley et al., 1998). The initiation of change provides numerous opportunities for new ways to work with other people in the educational system such as principals, superintendents, and home-room teachers.

The program also emphasizes learning to work in new ways with other teacher leaders and educators. Several studies (e.g., Fullan, 1990; Loucks-Horsley et al., 1998; McLaughlin, 1991) suggest that teacher collegiality and collaborative work environments are critical to change. We expand this idea to include teacher leaders and educators' collegiality and collaboration. Throughout the program we emphasize the development of a professional community. For example, the participants conduct several tasks in teams and make team presentations. We encourage them to open their work to colleagues, both for critique and use. Teachers read each other's yearly portfolios for feedback and give oral presentations to other course participants, to other mathematics educators in national conferences and meetings, and to administrators such as school principals and superintendents.

Manor Resource Materials

To teach effectively, teachers need materials such as textbooks, teacher guides, educational software and enrichment materials. Similarly, if inservice teacher learning is taken seriously, teacher educators need materials that are developed for the purpose of planning and executing learning experiences for inservice teachers. Thus, the Manor Project staff members develop research-based materials for use by teacher educators and teacher leaders (either the Manor Program participants or others). The guiding principle in designing the materials is that teacher leaders and in-service teacher educators should enhance teacher learning, where the role of the teacher changes from one who only implements expert-made curriculum materials, to one who sets subject matter goals and creates classroom environments to pursue them; from one who only implements decisions made by "knowledge owners," to one whose professional knowledge is broad and who can make professional decisions thoughtfully.

Three resource files have so far been developed on the topics of algebra, functions and pi. The major themes in these files are:

- A historical view on the main topic of the file.
- Selected mathematical aspects relevant to teaching the topic.
- Students' conceptions and ways of learning and thinking.
- Aspects of mathematics lessons and teaching.

The resource files contain detailed suggestions for teacher development meetings on the above themes such as mathematical, cognitive, social, and didactic aspects of teaching and learning. All suggestions were tried in previous inservice activities, including the Manor Program. In addition, they contain a classified list of articles, books, journals, and other references that can assist teacher educators and teacher leaders in their work.

The content of some of the suggested meetings is specific to the file's topic (e.g., historical view on the development of algebra, different representations of function, students' conceptions of pi) while others emphasize more general teaching and learning aspects in mathematical contexts (e.g., characteristics of a "good problem" in school algebra, comparative analysis of textbooks on functions).

Several models for teacher development meetings are exemplified, in order to suggest and illustrate ways of conducting such meetings. The aim is to convey the message that there is more than one way. All models are based on current ideas and conceptions about student learning of mathematics, modified to fit the context of teacher learning about mathematics teaching. Some examples include: encouraging teachers to explore and struggle with complex problems in the teaching of mathematics, emphasis on long-term investigations of problems, providing opportunities for cooperative learning, and supporting the development of powerful tools to solve problems in mathematics teaching.

Most entries in the resource files are presented in considerable detail with the aim of "portraying" a concrete, tangible picture of potential teacher development meetings including the rationale, atmosphere, ways of work, nature of discourse and materials. The suggested meetings include questions the teacher educator might wish to ask, responses that teachers who participated previously in such a meeting suggested and possible actions. In many cases, alternative suggestions are offered, as well as follow-up activities. Also, many teaching aids are included (e.g., worksheets, transparencies, video clips for illustration and discussion). In addition to the detailed entries there are also several less detailed suggestions which the users of the file can develop further.

The entries are developed to serve as a resource, model and guide; and indeed, teacher leaders and educators use the resource files in various ways to suit their context, taking into account the teachers with whom they work, the time available, and their own professional and personal preferences. For example, teacher educators use the materials as (a) a script and almost replicate the suggested activities, (b) as a resource for designing a different activity, and (c) as a source for professional development of the teacher educators themselves with no immediate use with teachers in mind.

Summary and Conclusions

Until the 1990s, most of the efforts in trying to achieve desired changes in school science and mathematics centered on the development of improved curricula. In the last decade, more attention has been gradually given to the teacher, as past educational reform efforts suggested that the teacher plays a critical role in the ways reform ideas are implemented in the classroom. It was realized that teachers' need to learn to teach in new ways cannot be ignored. Consequently, there was a need to change inservice work with teachers. The establishment of regional teacher centers creates a comprehensive framework that can provide opportunities for inservice teachers for life-long learning in their profession.

This chapter focuses on the development of teacher leaders in chemistry and in mathematics, part of a national endeavor to improve science and mathematics teaching and learning in Israel. After graduation, most fulfill the role of a teacher leader and educator, either in the newly-established regional teacher centers, in other local institutes that provide professional development for teachers, in their own school (as chemistry or mathematics coordinators), or in other schools. In addition to their leadership roles, most continue to teach chemistry or mathematics at school. Participating in the course is not a one time connection with the national teacher center, as most of our graduates continue to be in close contact with the center, either by regular or electronic mail, participation in one day workshops and lectures, or participation in a monthly forum.

In a summary questionnaire, the participants reported that participating in the teacher leaders' courses contributed to their being able to initiate and conduct change in school chemistry or mathematics, provided them with leadership knowledge and skills, expanded their teaching knowledge and skills, acquainted them with major figures in academia and the educational system, and motivated them to pursue further professional development and even graduate studies. Interviews with a sample of the participants and informal talks with others provided similar results.

Achieving scientific and mathematical literacy for all has become a national goal for education in many countries. Although admirable, the goal represents a challenge for science and mathematics teachers and for those responsible for professional development. Achieving this goal must be accompanied by reform in the way science and mathematics is taught in schools. Thus far, there is little literature which describes models and case studies that can help in building an educationally effective framework of professional development, especially in the development of leadership. The Israeli experience, described in this chapter, is intended as a small contribution in this direction.

References

Bell, B., & Gilbert, J. (1994). Teacher development as professional, personal, and social development. *Teaching and Teacher Education, 5*, 483-497.

Bell, B., & Gilbert, J. (1996). *Teacher development.* London: Falmer Press.

Bybee, R. W. (1997). *Meeting the challenges of achieving scientific literacy.* Paper presented at the meeting of the International Conference on Science Education, Seoul, Korea.

Clarke, D. M. (1993). *Influences on the changing role of the mathematics teacher.* Unpublished doctoral dissertation, University of Wisconsin-Madison.

Even, R. (in press-a). The development of teacher-leaders and in-service teacher educators. *Journal for Mathematics Teacher Education.*

Even, R. (in press-b). Integrating academic and practical knowledge in a teacher leaders' development program. *Educational Studies in Mathematics.*

Fullan, M. G. (1990). Staff development, innovation, and institutional development. In B. Joyce (Ed.), *Changing school culture through staff development* (pp. 3-25). Alexandria, VA: Association for Supervision and Curriculum and Development.

Fullan, M. G., (1991). *New meaning of educational change.* New York: Teachers College Press.

Hofstein, A., Ben–Zvi, R., Samuel, D., & Kempa, R. F. (1977). Modes of instruction in high school chemistry. *Journal of Research in Science Teaching, 14*, 433-439.

Hofstein, A., & Kempa, R. F. (1985). Motivating aspects in science education: An attempt at an analysis. *European Journal of Science Education, 7*, 221-229.

Hofstein, A., & Walberg, H. J., (1995). Instructional Strategies. In B. J. Fraser & H. J. Walberg (Eds.), *Improving science education: An international perspective, NSSE yearbook* (pp. 1-20). Chicago: The University of Chicago Press.

Kempa, R. F. (1983), Developing new perspectives in chemical education. In A. Rambaud & H. W. Heikkinen (Eds.), *Proceedings of the Seventh International Conference in Chemistry, Education, and Society* (pp. 34-42). Montpellier, France.

Kempa, R. F., & Diaz, M. (1990). Motivational traits and preferences for different instructional modes in science. *International Journal of Science Education, 12,* 195-203.

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. E. (1998). *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA: Corwin Press.

McLaughlin, M. W. (1991). Enabling professional development: What have we learned? In A. Lieberman & L. Miller (Eds.), *Staff development for education in the 90s* (pp. 61-82). New York: Teachers College Press.

National Council of Teachers of Mathematics (NCTM). (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (NCTM). (1991). *Professional Standards for Teaching Mathematics.* Reston, VA: Author.

National Research Council (NRC). (1996). *National science education standards.* Washington, DC: Author.

Robinson, N. (1993). *Connectedness in teaching: Equivalent algebraic expressions - by expert and novice teachers.* Unpublished master's thesis, (in Hebrew), Tel Aviv, Israel: Tel Aviv University.

Romberg, T. A., & Pitman, A. J. (1990). Curricular materials and pedagogical reform: Teachers' perspective and use of time in the teaching of mathematics. In R. Bromme & M. Ben-Peretz (Eds.), *Time for teachers: Time in schools from the practitioner's perspective* (pp. 189-226). New York: Teachers College Press.

Superior Committee on Science Mathematics and Technology Education in Israel. (1992/1994). *Tomorrow 98: Report.* Jerusalem, Israel. Ministry of Education, Culture and Sport (English edition: 1994).

Tamir, P. (1972). The practical mode, a distinct mode of performance in biology. *Journal of Educational Measurement, 6,* 175-182.

Tobin, K., Capie, W., & Bettencourt, A. (1988). Active teaching for higher cognitive learning in science. *International Journal of Science Education, 10,* 17-27.

11

Teachers' Perspectives: Developing Instructional Leadership Through Classroom Inquiry

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This chapter examines the role of inquiry in the development of instructional leadership in classroom teachers. It focuses on the impact that inquiry has on professional development, the promotion of professionalism, and collaboration through data-driven communication. The structure and function of leadership among these concepts serves as the organizing theme. Teachers' perspectives in acquiring, implementing, reflecting on, and restructuring their knowledge of inquiry and leadership in the profession of teaching are given to provide a first-hand narrative of those processes. These writings are taken from responses to interview questions, reflective journal entries, unsolicited teachers' writings, and conversations among educators in the Professional Development System of the Watson School of Education at the University of North Carolina at Wilmington. The teachers' narratives illustrate their passage through stages of professional development, leadership, and inquiry, and identify factors affecting the development and transition of the teachers through those stages. This chapter concludes with a summary of lessons learned about what teachers think and feel about leadership and inquiry and ways other educators can support teachers' leadership development through inquiry.

The Professional Development System (PDS) of the Watson School of Education at the University of North Carolina at Wilmington (UNCW) is a comprehensive university-public school partnership. This collaboration between higher education and public schools is designed to align efforts and resources for the improvement of both the quality of preparation for teacher interns and the performance of public school students in southeastern North Carolina and to close the gap between theory and practice. Approximately 750 educators affiliated with 47 schools in 10 school districts participate in formal collaborative agreements with the Watson School of Education. This collaboration is facilitated by ensuring that partners are responsive to each other and by widely disseminating knowledge about best teaching and administrative practices. All educators within the collaborating districts, known as PDS partners, have begun to redefine and clarify the professional roles of teachers, administrators, and university faculty in ways consistent with the needs and demands of the 21st century. The PDS partners, by combining, focusing, and utilizing their collective talents, knowledge, energies, and resources, are striving to achieve measurable improvements in classroom learning for all students at all levels. PDS activities include discussions and seminars sponsored jointly by school districts and UNCW, inservice workshops for renewal credit sponsored by school districts, inservice workshops sponsored by UNCW, and UNCW courses in learning-centered supervision.

A major PDS goal is to encourage research and inquiry by all partners. In accord with national and state standards for instruction, university and public school students are taught to use inquiry not only to learn curriculum but also to ask and answer questions about their own learning. University and public school faculty are engaged in variously-funded research agendas to examine the intracacies of the partnerships and their effects on public school and university students and teachers. All PDS faculty contribute to data collection for ongoing system-wide research while those who wish contribute to design, data analyses, and presentation phases. Partnership teachers are invited to participate in inquiry projects in order to facilitate understanding of the concepts of educational research and how that research can be conducted and applied in public school classrooms. Many teachers are initially reticent and somewhat unprepared to contribute to research efforts, especially at design and analysis levels.

In the secondary program, high school teachers are introduced to inquiry projects by assisting teacher interns who complete an inquiry project as a requirement during the internship experience. The interns had previously developed some facility with an inquiry project during coursework. Although the specific requirements of format varied by discipline area, all inquiry projects included documentation of decision making based on collection and analyses of data (Smith, 1998).

In ongoing discussions among university science methods instructors and public school science teachers, it was evident that teachers struggled with knowing how to acknowledge and express how they have come to know what they know. As part of inservice-credit workshops, teachers were invited to document the data collection and assessment associated with decision making and share that documentation as a Teacher-Directed Classroom Inquiry Project (TDCIP) (Rogers, 1998). The TDCIP was designed to address not only a need for a structure to support inquiry, but also to promote the professional development of those teachers.

Inquiry in Professional Development

The term professional development has been used in education to describe myriad activities conducted for the alleged improvement of educators. While some activities are designed to emphasize professionalism among participants through efforts designed to enhance self-esteem, content knowledge, or increased documentation of teaching events and other means of professional communication, other activities are designed to emphasize the developmental aspects such as assessing participants' growth on a selected variable, promoting participants' self assessment, or emphasizing particular factors associated with educator development.

Those professional development attempts which integrate components aimed toward promoting professionalism within a developmental context report higher gains in participants' satisfaction with the activity, increases in targeted variables such as content knowledge, and continued impact of the activity after its conclusion (Swanson, 1995). The goal of professional development is to assist in the formation of professional practice, that is, the practice of an educator who is knowledgeable in content and pedagogy (Shulman, 1981, 1998; Shulman & Sparks, 1992) and applies that knowledge consistently, competently, and confidently. That educator routinely assesses his or her knowledge and its application for ways in which to improve and routinely documents and communicates his or her practice with colleagues. This is a complex process requiring a repertoire of knowledge and experience in the area of practice (Hord, 1997). There is a clear need for inquiry within the context of professional development efforts (Byrd & McIntyre, 1999) if educators are to develop and objectively assess evolving competencies leading to professional practice.

In this context, inquiry can be defined as a search for information and insight gained through documented collection, analyses, and reporting of data. Although inquiry obviously provides a method to facilitate professional practice among educators (Banathy & Jenks, 1990; Lee, 1990; Maslin-Ostrowski, 1998; National Research Council, 1996; Swanson, 1995), many educators are hesitant or feel unprepared to engage in inquiry. Therefore, fostering a culture of inquiry within a specific educational system requires more than a statement of desire to do so (Banathy & Jenks, 1990; Hord, 1997; Lee, 1990; Oborn, 1996; Swanson, 1995; Watt & Watt, 1991). For these reasons, most novice inquirers respond favorably to a structured inquiry project (Hutchings, 1996; Fullan, 1993; Rogers, 1998; Watt & Watt, 1991). Inquiry projects assigned to teacher interns during the internship experience (Smith, 1998), whether conducted by practicing teachers individually or collaboratively with interns and other teachers, have been shown to facilitate thoughtful analysis and professional development in teacher practice (Wetherill, Rogers, & Calhoun, 1999). The inquiry project is seen as a means of documenting and thereby analyzing the decision-making processes inherent in teaching. Through the project the decisions are connected to the data collection means and sources (Rogers, 1999). Many teachers have stated that they do what they do because they know it works. Inquiry projects require a more thoughtful analysis of exactly what teachers are doing and how they are deciding what works.

In the TDCIP used in science inservice workshops (Rogers, 1998), teachers complete two tasks, the planning guide and the report guide. The planning guide directs the process of designing an inquiry project by helping teachers select an inquiry topic, consider additional information needed to focus on a particular inquiry, choose data sources and means of collection most likely to match their inquiry, determine how the data can be analyzed to address the inquiry, and acquire appropriate approval which may be especially important for teacher interns. The report guide structures a process of communicating results of an inquiry project, through stating the inquiry and appropriate background information, describing the procedure, findings, and conclusions of the project, explaining further implications of the project from the teacher's perspective, and providing references for interested readers. At the end of the internship experience, the teacher and teacher intern inquiry projects are shared among teacher interns, partnership teachers, and other school district and university educators to promote discussion of professional development issues through roundtable presentations. Teachers and interns report gains attributed to data-based discussions and decision making whch include greater confidence, professionalism, and sense of control of the variables associated with teaching.

Data-Based Collaboration

The key benefit to educators engaging in inquiry is the data-based collaboration made possible through conversations based on targeted data rather than opinion and inferences alone. When teachers engage in discussions about lesson design, material selection, homework choices, and other instructional decisions armed with the data carefully collected in their own classrooms, the tone focuses on professional considerations rather than personal considerations alone. Some teachers, especially newer teachers, report feelings of ownership and contribution to the profession and some teachers, especially more experienced teachers, report a willingness to reconsider strongly held concepts of viable practice (Rogers, 1999).

Leadership Through Inquiry

Leadership is needed, not only to promote documented inquiry, but also to encourage the use of data-based inquiry to make decisions (Hord, 1997; Lee, 1990; Maslin-Ostrowski, 1998). To be valid and useful to educators, inquiry requires a deliberately structured approach (Banathy & Jenks, 1990; Oborn, 1996; Rogers, 1998; Watt & Watt, 1991). Further, if leadership in educational settings is to be successful in meeting instructional goals, then it must promote collaborative, collegial relationships in authentic ways (Darling-Hammond, 1998; Swanson, 1995). Therefore, leaders who organize and communicate school culture in ways that promote authentic and collaborative inquiry approaches to decision making will be more likely to see progress in meeting instructional goals (Radford & Ramsey, 1996).

Most of the literature on leadership and inquiry points to school administrators as the instructional leaders of the school with the responsibility for setting the tone of inquiry in the school (Banathy & Jenks, 1990; Greenfield, 1987; Lee, 1990; Oborn, 1996; Peterson, 1985; Swanson, 1995; Wiggins, 1994). School administrators operating within a hierarchical leadership structure express difficulty with developing this level of involvement in teachers' professional development in addition to other managerial and organizational duties. Some arguments for teacher involvement in inquiry processes are often strong on symbolic involvement without specific suggestions for transitions to that ideal engagement, or conversely, provide subordinate tasks for teachers to complete without involving them in the overall inquiry design. Clearly, teachers who are authentically engaged in inquiry that is meaningful and professional will benefit most from inquiry (Acheson & Smith, 1986; Boyle & Skopp, 1998; Darling-Hammond, 1998; Fullan, 1993; Strodl, 1992) and will additionally develop leadership roles supporting instructional goals (Bird & Little, 1985; Larson, Mayer, Kight, & Golson, 1998; Rogers, 1999).

Instructional Leadership

Leadership among teachers has been promoted from a number of perspectives. If educators use inquiry as a way to document and evaluate decision making, then the role of leadership is to focus decision making on appropriate data collection and analyses. Leaders who promote clearly-communicated goals for the inquiry will be in a better position to see those goals met because others conducting inquiry will be seeking to collect and analyze data to address similar concerns. For example, a focus on what conditions best help ninth grade students perform better on an end-of-course achievement test is different from a focus on preparing eighth graders to use higher order reasoning skills. Leadership using an inquiry approach requires a clear and readily communicated focus on instructional goals in order to provide the framework for teachers' inquiry. We will use instructional leadership to mean a focus on communication, organizational structure, and professional development that promotes instructional goals above other goals. This is accomplished through an inquiry approach to data-based decision making.

In the past, instructional leadership was considered the domain of administrators who imposed practices and structures from the top down. Many of the leadership models were borrowed from business, medical, and other organizations and modified in an attempt to fit the educational arena. The extent to which those models have been successful seems to be the degree to which they acknowledge and incorporate a focus on instructional goals from a perspective of intentional inquiry (Banathy & Jenks, 1990; ERIC, 1987; Irwin, 1985).

A useful leadership model for educators is one in which the structure of the model supports the functions leading to the targeted instructional goals (Blase & Blase, 1998; Erickson, 1991; Krug, 1992; Larsen, 1987; Lee, 1990). For example, if the goal were a significant increase in third-grade students' mathematical reasoning skills, it would be counter-productive to reward teachers for students' performance on a standardized test that did not measure mathematical reasoning skills but assessed memorization of discrete mathematical information. It would be further detracting to measure teachers' leadership skills in terms of how many other third-grade teachers were convinced to promote memorization of those discrete facts alone. Consider, however, the impact of students, teachers, administrators, and project directors making decisions about progress by analyzing formative and summative assessments of the actual targeted goal and bestowing rewards based on measured growth. Measuring progress within the context of an inquiry approach provides meaningful data and analyses upon which rewards may be based. Student, teacher, and administrator efforts tend to be focused on what is rewarded; therefore, rewarding what is stated as the goal of a model, in response to collection of data measuring progress toward that goal, is more likely to promote attainment of that goal (Krug, 1991; McEwan, 1994). Clearly, data collected for accountability instruments presently used can be a meaningful and necessary tool in the classroom. Instructional leadership dramatically impacts the uses and purpose of these data. Measuring progress within the context of an inquiry approach provides the most meaningful data and analyses (Hord, 1997; Lee, 1990).

Teachers' Perspectives: The Stages of Inquiry

Teachers who acquire and implement inquiry processes in their decision making move through transitional stages as they develop conceptual understanding and facility with those processes. In order to document and clarify transitions, an inquiry project was conducted to examine communication documents and products of science teachers learning to use inquiry. As part of district-sponsored inservice science workshops, teachers participated in a series of meetings over the school year focusing on learning to implement inquiry projects (Rogers, 1999). These teachers also participated in PDS-sponsored seminars and attended meetings with other PDS colleagues. The following is a collection of teachers' perspectives in acquiring, implementing, reflecting on, and restructuring their knowledge of inquiry and leadership in the profession of teaching. These quotations are taken from responses to interview questions, reflective journal entries, and unsolicited teacher writings and conversations among educators in the PDS. The teachers' comments direct us to examine three stages of inquiry as well as the professional development and leadership issues associated with each. These three stages emerged from qualitative analyses of 57 teachers' work during two academic years.

The three stages of inquiry described, Beginning Inquiry, Transforming Inquiry, and Leadership Through Inquiry, include transitions in self-confidence, professionalism, collaboration, collegiality, and leadership.. Data from three science teachers--with the pseudonyms Beth, Nasheem, and Dodson--are given in order to highlight the identifying characteristics of each stage. Beth is a 48-year old female, a first grade teacher who has taught grades K-4 for 17 years in the same school district, and serves as a science and mathematics consultant for her district. Nasheem, a 25-year old female, is a seventh and eighth-grade general science teacher with 2 years of experience. Dodson, entering a second career at 51, is a lateral-entry high school physics and chemistry teacher with 30 years of military service, which included some instructional duties.

Beginning Inquiry Stage

Teachers at this stage must first accept the notion that all teachers are capable of conducting inquiry. With little or no experience at documenting their work, and little confidence in their own conclusions about their work, Nasheem and Beth began the inquiry projects from different levels of teaching experience, but similar levels of understanding about using inquiry in their own work.

Nasheem was asked by her department chair to participate in a TDCIP workshop. She attended each meeting and dutifully completed the associated tasks, but was initially hesitant to talk about anything not previously mentioned by others. For example, her first inquiry project was identical to a colleague's design and purpose; only her class data differed. She stated the same conclusions as her colleague, even though her data did not reflect two of those conclusions. In her analysis of the initial project she stated, "This is a different approach for me. I am more comfortable following an established curriculum. . . . it is rather disconcerting to question my teaching so directly." Nasheem was more comfortable as a follower and saw her professional development as the responsibility of school administrators: "I prefer to gather information about improving my teaching through workshops with many handouts and resources." As Nasheem listened to others sharing their projects, she began to take notes. At a break, she approached the workshop leader and asked, "Is it okay, you know, valid, for teachers to conduct their own studies?" In response to an affirmative answer, she said, "Then, I could learn anything about my class that I wanted, couldn't I?" After that break, Nasheem questioned other presenters about details of their design and data collection procedures. Her second inquiry project was her own design, an investigation of the differences in problem-solving approaches of seventh and eighth graders.

Beth participated in the same workshop and nodded affirmatively through introductory comments about the workshop's focus on inquiry in teaching. As discussion began, she provided examples of inquiry in her classroom conducted by her students. She stated convincingly, "Children learn through inquiry!" and others nodded in agreement. Beth then explained to us the role of inquiry in national and state standards for instruction in science and mathematics. Teachers continued to nod, then one expressed concern about misunderstanding—did inquiry in teaching mean inquiry done by students or by teachers? Beth turned and paused at that comment, then looked to the workshop leader and asked, "We are talking about inquiry in the curriculum, aren't we?" When told that inquiry was for students and teachers, Beth said, "Now, how in the world can I have time for that? I don't have a planning period. I spend my afternoons getting materials ready for my students' investigations. Besides, isn't that kind of inquiry really research that has to be done by experts?" Discussion continued into decisions teachers make and how those decisions are made. Beth later wrote in her reflection of the day, "It never dawned on me that I am conducting inquiry projects all the time. If I will just take the time and energy to document those, I can know more about what I am learning. I won't have to rely only on others' conclusions about teaching." Beth designed an inquiry project to examine her students' understanding of selected concepts as presented in student-led conferences with parents.

Nasheem and Beth each struggled with the role of inquirer, though from different levels of experience. Nasheem was less of a risk-taker than Beth. Nasheem was not aware that she could ask questions about the events of her teaching and Beth was not aware that she could ask her own questions. Both struggled with the issue of the validity of their work. This concern is common among teachers and teacher interns upon first encountering the idea of conducting their own inquiry. Activities and discussion to examine basic research design concepts often satisfy that concern. After such discussion Nasheem wrote in her reflective journal entry, "I am not yet ready to do the research that is generalized to other groups, but I am excited to study my own class and see what is real for us. I will document carefully what happens and ask for assistance in improving my design."

Both Nasheem and Beth overcame their initial beliefs that they were not competent to inquire about their teaching. Both developed ways of thinking about teaching that promoted data-based collaboration and decision making. The defining characteristic of the beginning inquiry stage is acceptance and implementation one's own ability to conduct inquiry.

Transforming Inquiry Stage

Some teachers begin as Nasheem and Beth did and then move into the transforming stage of inquiry. Others, like Dodson, already accept and or use inquiry processes. Dodson did not attend the initial workshop with Nasheem and Beth because he was not hired until after the workshop had begun. As a lateral entry teacher with no formal preparation in education, he was required to take selected courses at the local university. Dodson scheduled a meeting with the instructor of the secondary science methods course and walked in with a battery of questions. He was overwhelmed with the range of responses from the students and confused about why some lessons worked and others did not. Comparing his high school students with the military personnel he had trained for years, Dodson expressed displeasure with the lack of discipline and respect shown by high school students and the infrequent and inconsequential responses by administrators. "How am I supposed to teach in this chaos? I try what ought to work and sometimes it does and sometimes it doesn't. I'm not sure I should be a teacher." Armed with science education resources and a format for data collection, data-based discussions, and inquiry design, Dodson returned to his classroom and began the process of conducting his own inquiry. He had formed questions and used information to make comparisons of his students and the military personnel he had previously taught. What Dodson needed was a way to use his questions to change his practice.

A week later, he dropped by to report on his progress. "I think I'm getting a foothold in this. I needed to get more information about what the kids think. I had thought they'd learn chemistry and physics because those are interesting subjects, but the kids want it to be sensible to them, connected to their world. I have to make it meaningful. Now I'm going to try different ways of doing that." He described the inquiry projects to be conducted the following week and accepted advice about revisions. Subsequent weekly visits provided further refinement of his design and data analyses as well as a record of his conclusions.

At the end of the semester, Dodson wrote about his progress, "Looking back over my journal entries, I see that I have found a way to make sense of the chaos. I have ways of understanding what is happening and how my students are learning. I can directly assess their thinking rather than relying only on inferences from the chapter tests. I can see the kids going off course and make adjustments early rather than waiting for them to fail. Teaching is still extremely challenging, but it is within my reach."

Dodson's inquiries changed his perception of his own teaching and impacted his instructional practice. Dodson also found a change in his communication with other teachers. In another section of that same reflection, Dodson reported on his interactions with colleagues. "When I first started here, no one was interested in my opinions, only in telling me what I should do, and they didn't tell me the same things. Now when we talk about what works, I can show data from my inquiries. I don't have to defend my opinions, only share the data and what they mean to me. I've asked others to help me interpret the data and they have become interested in what I am doing. A couple of other teachers are trying out my inquiry projects in their classes. It's nice to have a professional level of discussion, rather than ranking opinions by years of experience." Dodson expressed a result often experienced by teachers who share their inquiry projects. He reported a higher level of confidence and professionalism in his interactions with colleagues. Data-based collaboration promotes professional discussion.

The key characteristic of transforming inquiry is that it impacts the teacher's practice, communication with other educators, and professionalism. Teachers who utilize inquiry processes find transforming effects throughout their use of inquiry. The transition to the leadership stage of inquiry is often subtle, usually beginning with a change in the focus and tone of conversations with other educators. Dodson began to see changes in his leadership coming from the changes in communication. By sharing what he wanted to know and how he was trying to learn, he led others to gather data with their own students. Dodson changed his perspective of the role of teacher. He began with a view of following orders and began to develop a sense of himself as instructional leader in his classroom, school, and district.

Leadership Through Inquiry Stage

Some teachers who use inquiry processes are already in positions of leadership and begin to show inquiry leadership characteristics with the first inquiry project. Many teachers who move to a leadership stage of inquiry transition into it, as Dodson did. In his conversations with other teachers, Dodson gently asked what data others had to support their claims. He shared his own data and began to collect research literature that reported on the topics he studied. He asked for explanations of theories said to support particular strategies. Dodson became a source of advice and support for other teachers and challenged them to know more about their own teaching. A teacher in Dodson's department remarked, "He has sparked some interesting conversations around here. Whenever we hear a claim for a new strategy or announcement of a new workshop, we take it to Dodson for his comments. Somehow that usually leads to us collecting data in our classes. It's great to have our own data to use in making decisions. You know, we looked at students' success and whether they took algebra before, after, or with chemistry. That information helped us make decisions about course sequencing as we switched to block-scheduled classes."

Beth was already in positions of leadership in her district. Many teachers and administrators counted on her to know the national standards, the state curriculum, and the district procedures and policies. Indeed, Beth had proven to be a strong resource. After accepting the role of inquirer, Beth began to question all those rules. She would often ask, "Why is this a good idea?" as she considered various aspects of what is expected of teachers. She decided that it wasn't enough to know what the mandates were; she needed to know why those positions were reasonable. She wrote, "Why should I take someone else's word for what works with my students? I can see for myself. When I hold workshops to tell others about the standards, or the curriculum, I can also show them how to test those ideas in their own classes." Beth was not questioning the standards from a position of refuting them, but from a position of better understanding the rationale for those standards.

Nasheem presented her inquiry projects at each of the monthly meetings of the inquiry workshop. At the end of that school year, Nasheem wrote about her thinking, "This has been quite an experience for me. I have learned how to look carefully at my teaching and my students' learning. I have also learned how to talk with other teachers about teaching and learning, not just to exchange 'war stories,' but to really talk about what we know and how we know it. Sharing my inquiry projects with others at these workshops has helped me to be more sure of myself." A mentor teacher at Nasheem's school reported that Nasheem was more involved in department and faculty meetings and seemed more relaxed about her interactions with other teachers. Nasheem turned to her and said, "I feel like one of the faculty now."

Lessons Learned

From the perspectives of Nasheem, Beth, and Dodson, as well as other teachers and teacher interns who have utilized inquiry projects, six lessons emerged. First, learning to use inquiry takes time, support, and willingness to take risks. Learning to use inquiry requires plenty of time to try out ideas, muddle through data, and reflect on conclusions. Periodic meetings over the course of an academic year are much more beneficial than one-shot attempts.

Second, as Beth and Nasheem explained, inquiry is often seen as something that experts must do. For teachers who are often overwhelmed with the range of expectations for their time, the idea of conducting inquiry too is not palatable. Teachers make many decisions a day and gather data with which to make those decisions; inquiry projects provide a structure for documenting that process so that it can be shared and refined. It is helpful for teachers to see inquiry as an organizing theme for the myriad tasks of the day-to-day routine. Teachers need to see themselves as inquirers.

Third, learning to use inquiry occurs more quickly and shows more impact on practice when the inquirer has many opportunities to discuss the process with other inquirers. Some teachers prefer to talk it through while others prefer to share written drafts and feedback, but the process of considering and reconsidering ideas should not be short circuited. In fact there seems to be no top limit for this activity. The more sharing of ideas that occurs, the greater understanding of concepts, inquiry processes, and impact on practice. Teachers need to know that it is fair to get ideas and advice from others. Inquiry need not be a solitary attempt and tends to be more effective as a collaborative effort.

A fourth lesson learned is that inquirers develop understanding of the concepts and processes of inquiry from more educated peers. As teachers gain success as beginning inquirers, they benefit from opportunities to learn research concepts, and to read and analyze research reports. Research is a form of inquiry and can provide structure and models for teacher inquiry. The difference between a beginning inquirer's project and a researcher's report is in establishing validity, reliability, significance, and if appropriate, the extent to which the study could be generalized. As research understanding and skills develop, teachers begin to see research as the inquiry of others and look for ways to establish and publish their own work as research.

A fifth lesson is that inquiry promotes professional development and is most effective in conjunction with teachers' established professional development activities. When teachers are engaged in inquiry projects, they begin, continue, or re-initiate professional development activities. New strategies, programs, and curricular materials are subjected to classroom testing. Collaboration efforts are focused on data-based decisions. Many teachers report seeing a connection between the inquiry projects and criterion-based licensure or certification standards. One teacher, a veteran of 23 years, reported, "I saw Nora go through the National Board Certification process last year and thought there was no way I wanted to work that hard. Now I feel like it makes more sense. There are several opportunities for inquiry within those tasks."

A sixth lesson and the focus of this chapter, is that inquiry promotes instructional leadership by providing a structure that is standard enough to be readily communicated, but flexible enough to address various questions, data sources, and issues in education. It is neither a simplistic nor linear approach. Rather, all instructional leaders, including teachers, must share a common vision and take risks to bring that vision to reality. Each must be willing to examine the results of appropriate data collection and analyses and act on the conclusions. Change is not easy to shepherd, but data-based discussions are more likely to encourage change. Support of those who take the risks of trying to change and endeavoring to grow is critical. Nasheem, Beth, and Dodson each had the advantage of department chairs and school administrators who supported their inquiry and data-based collaboration. Each had access to a science educator for resources, suggestions, and encouragement. Each had the advantage of sharing his or her work with receptive colleagues. Support is critical for instructional leadership and it must be ongoing, because teachers are not finished products, but rather works in progress (Darling-Hammond, 1998). One teacher described it this way:

> *We have realized and celebrated a lack of closure; we will never be finished because each lesson we learn poses new questions. We are resolved to look for progress in our growth, rather than seeking a sense of accomplishment in ending that growth.*

References

Acheson, K. A., & Smith, S. C. (1986). It is time for principals to share the responsibility for instructional leadership with others. *Oregon School Study Council Bulletin; 29*(6).

Banathy, B. H., & Jenks, C. L. (1990). *The transformation of education by design: A leadership guide for educational decision makers.* San Francisco, CA: Far West Lab for Educational Research and Development.

Bird, T. D., & Little, J. W. (1985). *Instructional leadership in eight secondary schools. Final report.* Boulder, CO: Center for Action Research, Inc.

Blase, J, & Blase, J. (1998). *Handbook of instructional leadership: How really good principals promote teaching and learning.* Thousand Oaks, CA: Corwin Press, Inc.

Boyle, R. A., & Skopp, L. (1998). *Teachers as inquirers: Constructing a model of best practice.* Paper presented at the 71st Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA.

Byrd, D. M., & McIntyre, D. J. (1999). *Research on professional development schools.* Teacher Education Yearbook VII. Thousand Oaks, CA: Corwin Press.

Darling-Hammond, L. (1998). Teacher learning that supports student learning. *Educational Leadership; 55*(5), 6-11.

ERIC. (1987). *The effective instructional leader. The Best of ERIC on Educational Management,* Number 91. Eugene, OR: ERIC Clearinghouse on Educational Management.

Erickson, G. L. (1991). Collaborative inquiry and the professional development of science teachers. *Journal of Educational Thought/Revue de la Pensee Educative, 25*(3), 228-45.

Fullan, M. G. (1993). Why teachers must become change agents. *Educational Leadership; 50*(6), 12-17.

Greenfield, W. (1987). *Instructional leadership: Concepts, issues, and controversies.* Newton, MA: Allyn and Bacon.

Hord, S. M. (1997). *Professional learning communities: Communities of continuous inquiry and improvement.* Austin, TX: Southwest Educational Development Laboratory.

Hutchings, P. (1996). *Making teaching community property: A menu for peer collaboration and peer review. American Association for Higher*

Education Teaching Initiative. Washington, DC: American Association for Higher Education.

Irwin, C. C. (1985). *What research tells the teacher about instructional leadership.* Paper presented at the 69th Annual Meeting of the National Association of Secondary School Principals, New Orleans, LA.

Krug, S. E. (1991). *Instructional leadership: A constructivist perspective. Occasional Papers: School Leadership and Education Reform, OP #7.* Urbana, IL: National Center for School Leadership.

Krug, S. E. (1992). *Instructional leadership, school instructional climate, and student learning outcomes. Project Report.* Urbana, IL: National Center for School Leadership.

Larson, J. O., Mayer, N., Kight, C., & Golson, C. (1998). *Narrowing gaps and formulating conclusions: Inquiry in a science teacher action research program.* Paper presented at the 71st Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA.

Larsen, T. J. (1987). *Identification of instructional leadership behaviors and the impact of their implementation on academic achievement.* Paper presented at the Annual Meeting of the American Educational Research Association, Washington, DC.

Lee, G. V. (1990). *Instructional leadership as collaborative inquiry: Opportunities and challenges.* San Francisco, CA: Far West Lab. for Educational Research and Development.

Maslin-Ostrowski, P. (1998). *Case stories of principal practice: A collaborative inquiry approach to professional development.* Paper presented at the Annual Meeting of the Association for Supervision and Curriculum Development, San Antonio, TX.

McEwan, E. K. (1994). *Seven steps to effective instructional leadership.* Broadway, NY: Scholastic Inc.

National Research Council (NRC). (1996). *National science education standards.* Washington, DC: Author.

Oborn, C. S. (1996). *The integration of a theoretical and epistemological leadership style to the practical realm of school administration: A discussion of inquiry based leadership and the development of a research based school.* Paper presented at the Annual Meeting of the National Council of Professors of Educational Administration, Corpus Christi, TX.

Peterson, T. K. (1985). : *Using assessment data to promote the principal As Instructional Leader.* Paper presented at the Assessment and Policy conference of the Education Commission of the States and the Colorado Department of Education, Boulder, CO.

Radford, D. L., & Ramsey, L. L. (1996). *Experiencing scientific inquiry and pedagogy: A model for inservice training for science education reform.* Paper presented at the 69st Annual Meeting of the National Association for Research in Science Teaching, St. Louis, MO.

Rogers, L. N. (1998). *Teacher-directed classroom inquiry projects.* Apex, NC: Mindful Insights, Inc.

Rogers, L. N. (1999). *Data-based decision making*. Apex, NC: Mindful Insights, Inc.

Shulman, L. S. (1981). Disciplines of inquiry in education: An overview. *Educational Researcher; 10*(6), 5-12.

Shulman, L.; & Sparks, D. (1992). Merging content knowledge and pedagogy: An interview with Lee Shulman. *Journal of Staff Development, 13*(1), 14-16.

Shulman, L. S. (1998). Theory, practice, and the education of professionals. *Elementary School Journal; 98*(5), 511-26.

Smith, R. W. (1998). *Secondary teacher intern inquiry projects*. Wilmington, NC. University of North Carolina at Wilmington Watson School of Education Professional Development System.

Strodl, P. (1992). *A model of teacher leadership.* Paper presented at the annual meeting of the Eastern Educational Research Association, Hilton Head, SC.

Swanson, J. (1995). *Systemic reform in the professionalism of educators. Volume I: Findings and Conclusions. Studies of Education Reform.* Andover, MA: NETWORK, Inc.

Watt, M. L.; & Watt, D. L. (1991). *Classroom action research: A professional development opportunity for experienced teachers. (*Draft). Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

Wetherill, K. S., Rogers, L. N., & Calhoun, D. S. (1999). *Redefining professional career development: Implications for empowering all educators.* Paper presented at the Annual Meeting of the Association for Teacher Educators, Chicago, IL.

Wiggins, R. A. (1994). *The principal as instructional leader: Inducement or deterrent to teachers' personal professional growth?* Paper presented at the Annual Meeting of the Association for Supervision and Curriculum Development, Chicago, IL.

12

In Their Own Words: What Science and Mathematics Teacher Leaders Say are Important Aspects of Professional Development

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Reform in science education not only focuses on student learning but also on the changing role that teachers play in the reform movement. This change involves teachers assuming new leadership roles in both their classrooms and schools. The leadership role involves teachers bringing about school-wide change by involving their school colleagues in the decision-making process and empowering them to be the initiators, instead of the receivers of change. Professional development is integral in the preparation of teacher leaders involved in change. The FIRST Project was a statewide professional development program designed to develop a cadre of elementary science and mathematics teacher leaders in North Carolina. This chapter describes the elements of the 15 professional development programs that the teacher leaders found helpful when implementing their new leadership role in the school. The elements identified by the teacher leaders are embodied in three categories termed Knowledge of Content and Pedagogy, Delivery of Professional Development, and Leadership Skill Development

National groups including American Association for the Advancement of Science (AAAS), (1989, 1993), National Council of Teachers of Mathematics (NCTM), (1991), National Science Teachers Association (NSTA), (1992, 1993), and National Research Council (NRC), (1996) have called for reform in science and mathematics education. At the same time, national education reform reports (Carnegie Commission on Teaching as a Profession, 1986; Holmes Group, 1986) have recommended changes in teachers' roles. Thus, the reform movement not only focuses on student learning but also on the changing role that teachers play in the reform movement. The change in teachers' roles involves assuming new leadership. As leaders, teachers facilitate a change in both their classrooms and schools. Pellicer and Anderson (1995) argue that no school-wide change will occur unless teachers assume a variety of leadership responsibilities. These new responsibilities have teachers bringing about school-wide change by involving their school colleagues in the decision-making process and empowering them to be the initiators, instead of the receivers of change.

Professional Development for Teacher Leaders

Professional development is integral in the preparation of teacher leaders. These programs must provide learning experiences that help deepen teachers' understanding of science content and pedagogy (Loucks-Horsley, Hewson, Love, & Stiles, 1998). In addition, these programs must provide opportunities for teachers to develop their leadership skills (Miller, Wallace, DiBiase, & Nesbit, 1999). As such, teacher leaders will be equipped with the requisite skills and knowledge to initiate and facilitate reform that best suits the culture of their respective schools. Research on adult learning and development shows that a passive, one-size-fits-all approach to professional development will not effect school-wide change (Howe & Stubbs, 1997). If the end result of professional development is to help teachers become agents for school-wide reform in science and mathematics education, then designing professional programs different from those which have been employed in the past is crucial. All too often, approaches to professional development employ a passive format in which reforms are dictated by state and national authorities. What is needed for the present and the future however, are professional development experiences designed to prepare teachers to assume a leadership role and effect school-wide change. One such approach to professional development was implemented in North Carolina. After participation in the North Carolina initiative (Franklin, 1993), as part of the project evaluation, the teacher leaders identified the aspects of professional development that helped them to assume a leadership role.

North Carolina's Lead Teacher Initiative

The North Carolina Mathematics and Science Education Network (MSEN) sponsored a statewide professional development program (Franklin, 1993) designed to develop a cadre of elementary teacher leaders in science and mathematics. A teacher leader was a classroom teacher who volunteered or was selected to participate in a professional development experience and then return to school and work with colleagues to effect change. The responsibilities assumed by the teacher leaders were in addition to their regular teaching schedule (Miller, Wallace, & Nesbit, 1997). The initiative used teams of two full time teachers and their school principal, who agreed to collaborate with their school colleagues to bring about improvement in mathematics and science instruction. The project was funded by the U. S. Department of Education Fund for the Improvement and Reform of Schools and Teaching (FIRST).

The FIRST Project (Franklin, 1993) prepared the teams to assume a leadership role at the local school level through learning experiences designed to strengthen their science and mathematics content, pedagogical knowledge, and leadership abilities. Fifteen professional development programs were designed and implemented at eight university sites over a three-year period. Three hundred and fifty-four teachers from 180 schools were involved in the two-year professional development programs, which included pre-assessment sessions, a summer institute, academic year follow-up sessions and a culminating workshop held the following summer. The selection of teacher leaders by building principals was based on the following criteria: teachers who were well grounded in mathematics and science content background, teachers who were recognized as excellent classroom teachers, and teachers who demonstrated good communication skills. However, many of the participating teachers did not meet the desired criteria. In some schools, teachers volunteered and in others they were designated. As such, the teacher leaders were only slightly better prepared than other teachers at their school in that they reported taking more content related coursework and also were more often enrolled in advanced degree programs (Franklin, 1993).

The 15 professional development programs all included four similar core elements: curriculum, instruction, assessment, and administrative support. Each program was based on the school's Needs Assessment (Franklin, 1990) and therefore, each program had its own unique mix of the four core elements that supported content and leadership development. However, all programs devoted at least 60% of the time to content and pedagogy and from 18% to 40% to leadership (Miller et al., 1997). Programs also varied in the type of activities and the type of presenters involved with the professional development.

An important question emerged during the project's implementation. What aspects of the professional development programs would the teacher leaders find helped them in implementing their new leadership role in the school? Analyses of what the teacher leaders said provided the answer to this question (Nesbit, Wallace, Miller, & DiBiase, 1998).

Qualitative and quantitative data were gathered from 288 of the 354 teacher leaders who began the project. Data from the teacher leaders were collected from three different sources: two written assessments completed by all participants and structured individual interviews with a randomly selected subgroup of 30 teacher leaders from 15 different schools. The written post-program assessment included Likert scale items and open-ended questions (Franklin, 1993). In the Likert scale items, the teachers were asked to rate the importance of 17 different aspects of the program in helping them carry out the project at their schools. The open-ended assessment consisted of two questions: What aspects of the project helped the most? and What would have helped more? The Structured Interview Protocol (MSEN, 1993) included 50 questions, seven of which focused on the teacher leaders' perceptions of the 15 professional development programs. "Think of some specific things in this project that have helped you most in your role as a teacher leader and tell me about them" is an example of the type of question posed.

What Teacher Leaders Had to Say

Three broad categories emerged during the analysis of the data gathered from the teacher leaders (Franklin, 1993; Nesbit et al., 1998). The categories were termed: (1) Knowledge of Content and Pedagogy, (2) Delivery of Professional Development, and (3) Leadership Skill Development. Leadership Skill Development included subcategories identified in a previous study (Miller et al., 1997): Knowledge of Leadership Content, and Planning and Practice of Leadership Skills. The three major categories involved a number of factors that varied by programs in the amount of time they were used or implemented. Figure 1 depicts the relationship of these three overlapping categories and factors. In this chapter, we discuss the categories and related factors.

Knowledge of Content and Pedagogy

The FIRST Project involved teacher leaders in activities that included subject matter knowledge and teaching strategies. Knowledge

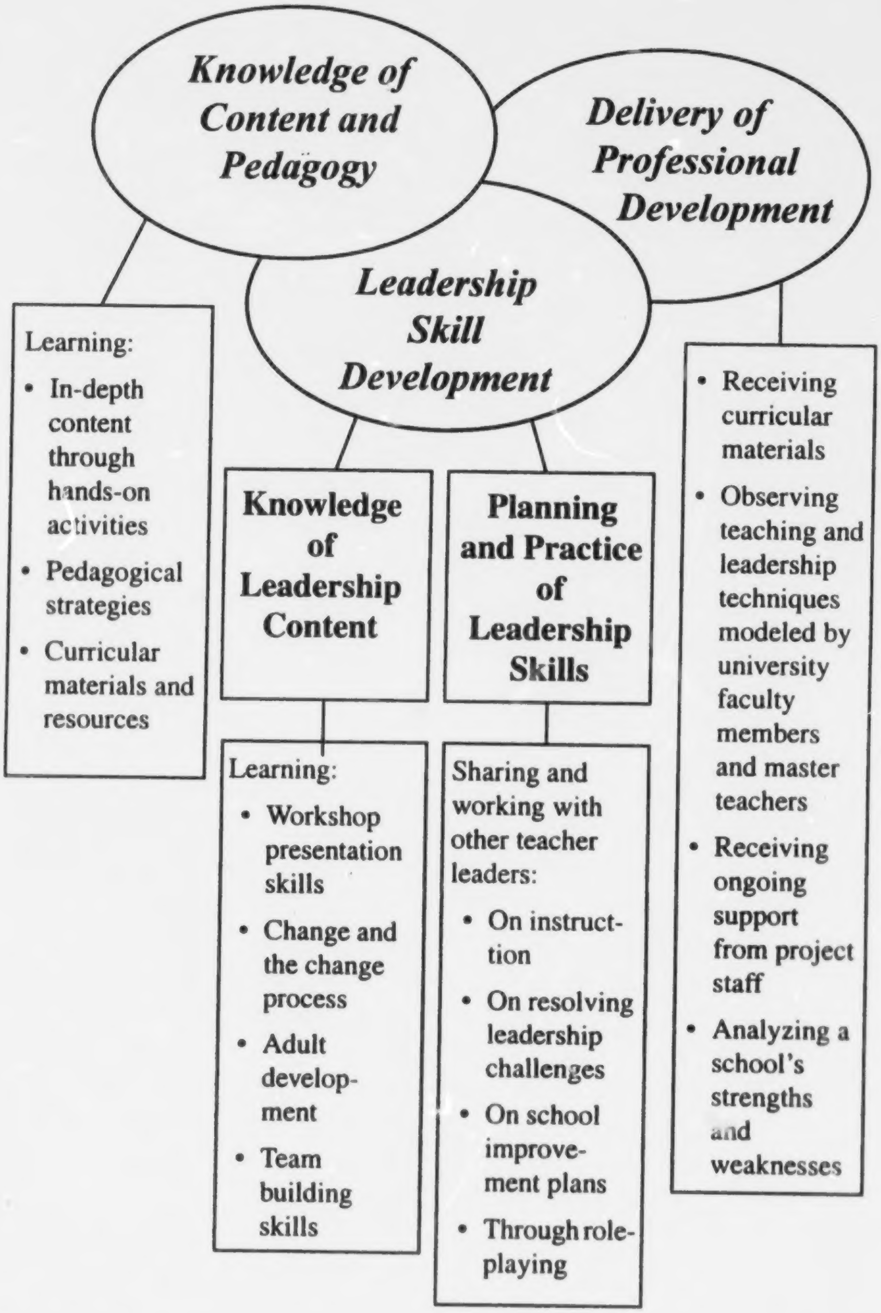
Knowledge of Content and Pedagogy
Delivery of Professional Development
Leadership Skill Development
Learning:
• In-depth content through hands-on activities
• Pedagogical strategies
• Curricular materials and resources
Knowledge of Leadership Content
Planning and Practice of Leadership Skills
Learning:
• Workshop presentation skills
• Change and the change process
• Adult development
• Team building skills
Sharing and working with other teacher leaders:
• On instruction
• On resolving leadership challenges
• On school improvement plans
• Through role-playing
• Receiving curricular materials
• Observing teaching and leadership techniques modeled by university faculty members and master teachers
• Receiving ongoing support from project staff
• Analyzing a school's strengths and weaknesses

Figure 1. Important Factors in Professional Development According to Teacher Leaders

of Content and Pedagogy is a category within the professional development experience that includes "presentations directly related to science, mathematics, or both" (Miller et al., 1997, p. 10). Topics and activities related to content and pedagogy and those that integrate content and pedagogy were assigned to this category, which emerged as the most important one to the teachers with 61% of the total responses. The category of Knowledge of Content and Pedagogy includes learning in-depth content through hands-on activities, learning pedagogical strategies, and learning about curricular materials and resources.

Learning in-depth content knowledge meant that teachers needed more than a cursory introduction to a concept in order to understand it. Further, many teachers talked about needing to know developmentally appropriate concepts and student misconceptions about these concepts. One teacher said:

> *It made me feel confident about science, where I hadn't before, and it made me feel like I had the background that I needed and was able to do it. Teachers need to have more knowledge in science and math. Things change. What I learned in college is far from adequate and I have a pretty good knowledge of science. New teachers are not any better prepared. Too much misinformation is shared.*

Learning through hands-on activities helped teacher leaders understand the subject matter. These learning experiences helped the teacher leaders bring their knowledge back to colleagues at their respective schools.

> *I would say almost even more than what we learned, the hands-on lessons were very impressive. That just stood out. I enjoyed it; doing everything and working through the whole process makes you take it back and do it yourself. Just all the physical science and the biological science,* [I] *remember a lot of those activities....The nature walks, the actual hands-on, not just sitting there listening to lectures but* [I] *really got in there and did everything with them.*

Learning pedagogical strategies implied that content should not be taught in isolation. Teacher leaders identified items on the post-program assessment that indicated they wanted content integrated with pedagogical strategies. In other words, as they learned the content, the teacher leaders also needed to learn effective teaching strategies. A teacher said:

> *Through this math workshop, I began to understand and learned a little more about how teachers taught fractions, or how they teach children to work with decimal points and things. These are things that I really never thought about, but as a lead teacher, you have to learn more about it, because you are responsible for giving ideas to those teachers in other grades besides just the ones that you're comfortable with.... Examples of how to teach certain hard-to-teach concepts.*

Learning about curricular materials and resources provided teachers with information about the many resources available to them. Not only did they find out about these resources, but they also found out how to order and obtain the resources for their schools. Teachers also noted the benefits of learning about materials management.

> *I guess the resources that we gained were most beneficial—people that we can contact, science programs that we saw and were exposed to, the technology we were exposed to. To know that there is so much out there kind of shook us awake. We had been just dreaming for years, and we didn't know how to dream. Learning what types of manipulatives are available and how to use them in order to teach better with children understanding.*

Delivery of Professional Development

Teacher leaders identified certain aspects of Delivery of Professional Development as important factors for them. Delivery of Professional Development is defined as the manner in which staff development is carried out and includes both who does the instruction and how it is presented (Miller et al., 1997). Of all the responses given, 20% dealt with this category. Delivery of Professional Development includes the following four aspects: receiving curricular materials and resources, observing teaching and leadership techniques modeled by university faculty and master teachers, receiving on-going support from project staff, and analyzing a school's strengths and weaknesses.

Receiving curricular materials and resources was identified as important in supplementing classroom materials for science and mathematics teaching. The project provided many of these materials to the teachers and in addition, the schools contributed funding for hands-on materials. The resources included calculators, videos, software, print materials, magnifying lenses, and other low cost items. One teacher said, "giving teacher leaders the resources they need to have an up-to-date program...having a notebook full of ideas and people to contact in coming years."

Observing teaching and leadership techniques modeled by university faculty and master teachers was valued by the teacher leaders. A master teacher in this project was a classroom teacher who was recognized for their instructional skills by serving as a co-instructor with university faculty. The presenters showed teachers how to teach and lead others by their own presentations. Comments such as the following verify teachers' interest in modeling:

> *The demonstrations by the faculty of the different hands-on activities helped me the most; being able to participate in these demonstrations enabled me to gain confidence in presenting it to others. Actually seeing the experiments being performed and doing our own experiments. Also watching our teachers when they explained to us how to do different experiments.*

There was praise for both university faculty and master teachers. However, there was more motivation for listening to master teachers. This is illustrated in the following teacher's quote.

> *It's easier to understand when there is someone from the classroom that has actually done this and they can tell you, this is how it works. Teachers who were experienced, hands-on practitioners were teaching.* [This was] *one of the most helpful aspects. I knew they were not just theorizing about what might work in a classroom.*

Receiving on-going support from project staff throughout the two year professional development program was a critical element for the teacher leaders. The professional development programs were sequenced to provide on-going support throughout the academic year. Helpful aspects according to one teacher were:

> *Support of project staff in our school endeavors. The folks gave us all direction to follow through with school goals. It was a part of each session. The follow-up sessions because they kept you in touch with what was going on and they made you think continuously about math and science.*

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In addition to the follow-up sessions, some project staff were in contact with the teacher leaders through telephone conversations and school site visits. One teacher leader spoke about this type of support as being helpful. Knowing "that I may contact the resident experts at [a local university] when I get stumped. I was helped during the school year with activities on probability that added a lot to my presentation of that concept."

Analyzing a school's strengths and weaknesses provided feedback for designing the professional development programs. The professional development programs were built on the needs of the individual schools. Each teacher and administrator completed a Needs Assessment, which was then analyzed by the teacher leaders (Franklin, 1990; Penta, Mitchell, & Franklin, 1993). With the Needs Assessment results in mind, the teacher leaders and administrators drew up a School Improvement Plan for each school with input from the school faculty. One teacher leader said that "The School Plan was most helpful in that we recognized weaknesses and began to build on them....evaluating our school's needs...seeing our weaknesses and working on them to meet our goals."

Leadership Skill Development

Teacher leaders identified components categorized as Leadership Skill Development as being important in their professional development program (Franklin, 1993). Nineteen percent of the teachers' responses fell into this category which included two subcategories: Knowledge of Leadership Content and Planning and Practice of Leadership Skills.

Knowledge of Leadership Content involved formal presentations of leadership skills (Miller et al., 1997). This subcategory included learning workshop presentation skills, learning about change and the change process, learning about adult development, and learning team building skills.

Learning workshop presentation skills enhanced the teacher leaders' ability to work with others at their school. One teacher said:

> *How to teach a workshop, how to make it interesting, how to plan for the comfort of the other teachers as far as just physical things because I had never done a workshop before that was very helpful in being a lead teacher.*

Learning about change and the change process was particularly beneficial as teacher leaders went back to their schools and began introducing innovations to their colleagues. As is recounted in the following quote, the teacher leaders went to their colleagues filled with enthusiasm and were often met with far less enthusiasm. "I think any kind of change takes time and I think if you try to go in there like a gang buster and say, this is the way its going to be, you're going to fail."

Learning about adult development is vital as working with adults differs from working with students in the classroom. As such, learning about adult development is an important aspect of a professional development experience for teacher leaders. The teacher leaders reported that this information helped them get their school faculty "on board" when changes in science and mathematics instruction were introduced. The teacher leaders recognized the need to be aware of other teachers' perspectives when supporting them during the change process. The teacher leaders also discovered that experienced teachers were in a very different place compared to beginning teachers. One lead teacher expressed this by saying that you, "have to be a wonderful listener first before you can be a leader to find out where people are coming from...learning about adults' learning process." This was one teacher's story:

> *At our school, I think one of the things that has changed for me, particularly as a lead teacher, is that now I've become more of a counselor to the teachers with experience. Beginning teachers are willing to try anything. So I have to encourage them [the veteran teachers] by almost providing the lesson. I've done that for some teachers who've taught as long as I have.*

Learning team building skills assisted teacher leaders as they involved their colleagues in taking ownership in developing and sustaining the innovations at their schools. These teacher leaders saw the importance of getting their teachers involved in the decision-making process in order for change to take place. A shift in perspective took place as they saw their role changing. One teacher expressed it this way:

> *When I first thought about it [the role of lead teacher], I thought that all I'd have to do was come down here [to the professional development program] and get the information and just give it to them [teachers at my school] and let them do whatever they wanted to. But I see now that I need to get*

> *more of my faculty involved...showing me how to get the 'outs to be in.'*

Another teacher added, "Helping me to be more confident of myself so that I could be a model and encourage others. The team building and 'bringing outs in' was very beneficial."

Planning and Practice of Leadership Skills included the opportunity to develop and use leadership skills (Miller et al., 1997). This subcategory included sharing and working with other teacher leaders on instruction, on resolving leadership challenges, on School Improvement Plans, and through role-playing.

Sharing and working with teacher leaders on instruction provided opportunities for exchanging expertise. Often the teacher leaders either taught or co-taught the learning sessions. One teacher's comment reveals her opinion about the helpfulness of input from other teachers.

> *I think one of the plusses in it was how we were able to share with teachers from other classrooms. You see, if I'm doing this and you're doing that and somebody else is doing another thing and if we can sort of get together and share, maybe something that I'm doing can help you and maybe something that you're doing can help me.*

Sharing and working with other teacher leaders on resolving leadership challenges included reflection and problem solving. Teachers faced a number of challenges as they implemented the project at their respective schools. For example, the resistant teacher who refused to get "on board" confronted many of them. By having the opportunity to share both their expertise as well as the successful experiences of other teachers, the teacher leaders were able to solve many school-based problems. Teacher leaders expressed support for the sharing theme when they said:

> *Sharing experiences was most beneficial. At the time we first went to* [the follow-up sessions], *we were concerned because our staff was not pulling together for the* [school-wide] *workshop. They* [the other teacher leaders] *gave us some good suggestions, like modeling these activities, having the workshop on a regular school day, and calling in volunteers.* [It was] *great because our whole staff participated, all of our teachers participated* [in the workshop].

> *Having the time to talk out the problems you're having, and are you having this at your school? Well, how could we do this? How could we go over this challenge? I think that was a great strength.*

Sharing and working with other teacher leaders on School Improvement Plans gave structure for the teachers to share and support each other during the professional development program as well as during the implementation phase in the school. Leadership teams were normally comprised of two teachers from each school, one teacher from the primary grades and the other from the intermediate grades. One of the projects that the leadership team worked on together was developing, presenting, revising and implementing the School Improvement Plans. Many teacher leaders took their School Improvement Plan back to school and presented it to the teachers in order to solicit support. One leader spoke about the support she received from her fellow lead teacher as she presented the School Improvement Plan.

> *When the other lead teacher came for observations with me that helped me tune in on what I needed to do as far as presentations because several of her observations were of me presenting to the faculty...having a support from someone at school...developing a School Improvement Plan.*

Sharing and working with other lead teachers through role playing gave teachers the opportunity to plan and practice leadership skills and lesson presentations.

> *The person who did our leadership session was tremendous. She knew exactly how to get us fired up, and showed us how to go about improving our leadership skills. And the other lead teacher was a tremendous support and we practiced leadership with each other.*

Another teacher said:

> *The biggest thing that I learned is that I could get up in front of a group and present a lesson and I can do it without dying, realizing that, yes, I do have some lead teacher capacity here.*

Conclusions and Implications

The teacher leaders identified a number of varied learning experiences that were needed to prepare them for a leadership role and to help them to effect school-wide change. The elements identified by the teacher leaders are embodied in the categories termed Knowledge of Content and Pedagogy, Delivery of Professional Development, and Leadership Skill Development. Each category is comprised of a number of elements which teachers said were important in preparing them for their leadership role.

Teacher leaders' comments reflected on the value of including Knowledge of Content and Pedagogy in the professional development experience. The elements included in the Knowledge of Content and Pedagogy category are well cited in the literature. A report by the U.S. Department of Education (Sivertsen, 1992) notes that "teachers need to know the discipline, to understand the key ideas, and their relationship to each other" (p. 21). Knowledge of the discipline is vital for effective instruction (Loucks-Horsley et al., 1998). However, content knowledge alone is not enough. Time must also be allotted for the development of pedagogical content knowledge. According to Schulman (1987), pedagogical content knowledge includes an understanding of the content, knowledge of students' misconceptions, developmentally appropriate concepts, and instructional strategies that will help students learn.

In addition to Knowledge of Content and Pedagogy, the teacher leaders identified a number of helpful aspects related to Delivery of Professional Development. The elements in this category are also supported in the literature. Zinn (1997) reports the benefits gleaned from leadership modeling. The NRC (1996) also notes the importance of demonstration and modeling techniques. In addition, both the NRC (1996) and Loucks-Horsley (1998) recognize that receiving instructional materials plays an important role in promoting teacher change. Furthermore, knowledge of a school's climate, the principal's commitment to reform, and the district's priorities all play a role in how well a newly-defined teacher leader can help bring about change (Fullen, 1993). Using a needs assessment at the beginning stages of the professional development experience helps the emerging teacher leader to address both the needs and goals of their school and district.

Another important factor the teacher leaders identified was receiving support from project staff. Researchers such as Bennis

(1989), Garmston (1988), Leithwood (1992), and Pellicer and Anderson (1995) encourage including a way to ensure that the teacher leaders have support as decision-makers. Lieberman (1995) and Darling-Hammond (1995) report the need to include support from key school system personnel. The active involvement of principals is recognized by Hanson, Thompson, and Zinn, (1993), Lieberman (1988), and Pellicer and Anderson (1995). Other researchers (Graebill & Phillips, 1990; Loucks-Horsley, 1992; Bolman & Deal, 1994; Bredeson, 1995; Wasley 1991) describe the benefits realized from supportive behavior from other teachers.

The teacher leaders also identified aspects categorized as Leadership Skill Development as important in their professional development experience. Leadership Skill Development includes both Knowledge of Leadership Content and Planning and Practice of Leadership Skills. Both aspects are essential ingredients of a professional development experience (Nesbit et al., 1998). There are very few studies that specifically include elements related to Knowledge of Leadership Content. However, Zinn (1993) notes that teaching presentation skills is a key aspect of professional development. More research is needed on the role played by Knowledge of Leadership Content in the development of teacher leaders.

Many professional development programs in science and mathematics provide subject content and pedagogy as well as aspects related to the delivery of professional development. However, these programs often leave out the development of leadership skills. Developers and facilitators of professional development for teacher leaders would do well to include time for the participants to share and work with others on instruction, role-playing and resolving leadership challenges.

Key Findings

As previously noted, attending to key concepts of the subject and teaching strategies as well as certain aspects of the design of the professional development program are important experiences for teacher leaders. However, a focus on Leadership Skill Development where teachers learn how to work with other teachers to bring about change is ofen neglected and is necessary because in assuming a leadership role teachers are often entering a new arena. There are excellent teachers of children who have never been exposed to the essential knowledge nor practiced the necessary skills needed to work with and lead other adults, specifically their peers. Teacher leaders cited certain elements of Leadership Skill Development, such as workshop presentation skills and working with other teachers on resolving leadership challenges, as important ingredients to be included in professional development programs. This unique category, Leadership Skill Development, has two subcategories, Knowledge of Leadership Content and Leadership Planning and Practice. Although teacher leaders acknowledge the importance of the inclusion of elements from both subcategories, they indicate of the two subcategories the specific elements of Leadership Planning and Practice were most crucial for them. In other words, what teacher leaders are saying is that once they receive a leadership knowledge base, they need opportunities to practice what they have learned through role playing and demonstration lessons with other teacher leaders.

In summary, the acquisition of new leadership skills is fostered by a number of experiences: the formal presentation of leadership topics, time for planning and adapting the knowledge to their own school setting and finally, practicing the skills the teachers have learned. Throughout such learning experiences, teachers report that they benefit from discussing and sharing with other teacher leaders, processing the information and receiving feedback from others as they practice their new skills.

These elements are cited by teacher leaders as being important ingredients to prepare them for their leadership roles in their schools. Having acquired and practiced these leadership skills, teacher leaders will be able to engage their school faculty in considering new ideas and collaboratively working to develop and implement school change that fits the needs of their school.

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References

American Association for the Advancement of Science. (AAAS). (1989). *Science for all Americans.* New York: Oxford University Press.

American Association for the Advancement of Science. (AAAS). (1993). *Benchmarks for scientific literacy.* New York: Oxford University Press.

Bennis, W. (1989). *Why leaders can't lead.* San Francisco: Jossey-Bass.

Bolman, L. G. & Deal, T. E. (1994). *Becoming a teacher leader: From isolation to collaboration.* Thousand Oaks, CA: Corwin Press.

Bredeson, P. V. (1995). Role change for principals in restructured schools: Implications for teacher preparation and teacher work. In M. J. O'Hair & S. J. Ode (Eds.), *Educating teachers for leadership and change* (pp. 25-45). Thousand Oaks, CA: Corwin Press.

Carnegie Commission on Teaching as a Profession. (1986). *A nation prepared: Teachers for the 21st century.* Hyattsville, MD: Carnegie Forum on Education and the Economy.

Darling-Hammond, L. (1995). Policy for restructuring. In A. Lieberman (Ed.), *The work of restructuring schools: Building from the ground up* (pp. 157-175). New York: Teachers College Press.

Franklin, M. E. (1990). *Mathematics and Science Education Network: Elementary school science and mathematics program assessment.* Chapel Hill, NC: University of North Carolina at Chapel Hill.

Franklin, M. E. (1993). *Statewide improvement in elementary mathematics and science education through peer teacher training* (Final Report of Project R168D00258-92). Chapel Hill, NC: University of North Carolina at Chapel Hill, Mathematics and Science Education Network.

Fullen, M. G. (1993). *Change forces: Probing the depths of educational reform.* Bristol, PA: Falmer.

Garmston, R. (1988). Empowering teachers: Some practical steps. *Thrust, 18*(2), 21-24.

Graebill, L. & Phillips, E. (1990). A summer math institute for elementary teachers: Development, implementation, and follow-up. *School Science and Mathematics, 2,* 134-141.

Hanson, L. J., Thompson, M. M., & Zinn, L. F. (1993). *Perceived behaviors of elementary school principals which promote teacher leadership.* Unpublished manuscript, University of Northern Colorado, Greeley.

Holmes Group (1986). *Tomorrow's teachers: A report of the Holmes Group.* East Lansing, MI: Holmes Group.

Howe, A. C., & Stubbs, H. S. (1997). Empowering science teachers: A model for professional development. *Journal of Science Teacher Education. 8*(3), 167-182.

Leithwood, K. A. (1992). The move toward transformational leadership. *Educational Leadership, 49*(5), 8-12.

Lieberman, A. (1995). Practices that support teacher development: Transforming conceptions of professional learning. *Phi Delta Kappan, 76*(8), 591-596.

Lieberman, A. (1988). Teachers and principals: Turf, tension, and new tasks. *Phi Delta Kappan, 69*(10), 648-653.

Loucks-Horsley, S. (1992). *Effective teacher development programs.* Presentation at the National Eisenhower Conference, Washington, DC.

Loucks-Horsley, S. (1998). The role of teaching and learning in systemic reform: A focus on professional development. *Science Educator,* 7(1), 1-6.

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. E. (1998). *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA: Corwin Press.

Mathematics and Science Education Network. (MSEN). (1993). *FIRST Project interview protocol.* Chapel Hill, NC: The University of North Carolina at Chapel Hill.

Miller, A.-C., Wallace, J. D., DiBiase, W. J., & Nesbit, C. R. (1999) *Pebbles in the ocean or fountains of change? New insights on professional development: Examining the links-professional development, teacher leaders, and school change.* A paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA.

Miller, A.-C., Wallace, J. D., & Nesbit, C. R. (1997). *Design of professional development for science and mathematics teacher leaders and resulting implementation in schools.* Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics.* Reston, VA: The Council.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

National Science Teachers Association (NSTA). (1992). *Scope, sequence, and coordination of secondary school science.* Washington, D.C.

National Science Teachers Association (NSTA). (1993). *A strategy for change in elementary school science.* Proceedings of a conference. Arlington, VA: Author. Washington, D.C.

Nesbit, C.R., Wallace, J. D, Miller, A-C., & DiBiase, W. J. (1998). *What science and mathematics teachers say are important aspects of professional development for teacher leaders.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA.

Pellicer, L. O., & Anderson, L. W. (1995). *A handbook for teacher leaders.* Thousand Oaks, CA: Corwin Press.

Penta, M., Mitchell, G., & Franklin, M. (1993). *Reliability study of needs assessment instrument for elementary school mathematics and science programs in North Carolina.* Paper presented at the Annual Meeting of the North Carolina Association for Research in Education, Greensboro, NC.

Schulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Education Review, 57*, 1-22.

Sivertsen, M. L. (1992). What research has to tell us about improving science teaching. *Improved science teaching and learning for the 21st century: Research-based perspectives on reform.* Washington, DC: U. S. Department of Education.

Wasley, P. A. (1991). *Teachers who lead: The rhetoric of reform and the realities of practice.* New York: Teachers College Press.

Zinn, L. F. (1997). *Supports and barriers to teacher leadership: Reports of teacher leaders.* Unpublished doctoral dissertation, University of Northern Colorado, Greeley.

13

The Professional Development of Effective Teacher Leaders

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The San Francisco Math Leadership Project was started in 1984 as one of the sites of the California Mathematics Project. During the past 15 years, nearly 500 elementary and middle level classroom teachers participated by attending a year long program which included an intensive summer institute and during the year activities. One goal was to provide a program that improved teachers' effectiveness by increasing their own confidence in learning and teaching mathematics. A second goal focused on developing teachers' leadership skills so that they could share their expertise with colleagues in their schools and participate in local conferences, thus enlarging the nucleus of mathematics leaders in the San Francisco Bay Area. The primary purpose of this chapter is to describe particular aspects of the project that have helped to develop leadership among the participants. It also describes the variety of leadership activities in which the participants have engaged over the years. Many of the outcomes could not have been predicted at the beginning of this project. It is only by looking back that we can really see the total impact of this long running professional development program.

In fourth grade my teacher was explaining long division. I just didn't get it. I knew I would eventually. But at that moment I was so frustrated—it seemed as though there were so many numbers and symbols all over the chalkboard.

I remember being very confused by word problems at the earliest years. I never knew where the numbers came from, but I was too afraid to ask....In high school, Geometry was a blur —I never knew when to apply the axiom I had memorized....I lasted two weeks in Algebra II and realized I didn't have a

> *clue. I dropped out knowing I would never take another math class.*
>
> *In college I took math and I had a foreign teaching assistant who was very hard to follow. ...The most annoying thing was he would madly write all these equations on the board, turn around to face the class, and say ' all clear? OK, I erase.' I never even had the chance to see what he was writing."*

Teachers wrote these memories on the first day of the summer institute of the San Francisco Math Leadership Project. They are surprised at how easily their memories of math teachers and math learning return. Each has a story to tell and it most often involves a specific teacher who can be recalled with amazing detail even after fifteen or twenty years.

Today, those involved with mathematics education have a major challenge. How can we provide the necessary support for elementary teachers, who often have negative memories of their math experiences, so they can bring the key elements of the national mathematics reform movement to their classrooms? Every elementary classroom teacher, is, in fact, a mathematics teacher. Yet, teaching elementary school is one of only a few professions that have minimal college requirements in mathematics. It is crucial that these teachers are able to provide opportunities for all children to learn and enjoy the challenge of mathematical thought. Teaching mathematics as problem solving, as communication, as reasoning and making mathematical connections, cannot wait for high school - elementary school is where it must begin.

Project Overview and Goals

Currently completing its fifteenth year, the San Francisco Math Leadership Project (SFMLP) is one of 17 sites of the California Mathematics Project funded by the State of California. Each site is connected with either the University of California (UC) or the California State University (CSU) system of higher education.

Collaboration among the teachers, principals, school district personnel and the university faculty has contributed to the success and impact of this project. At the local site level, the school district administrators and school principals play a major role in extending the project by utilizing the talents of teacher leaders who have participated in the project. This project and the other sites of the California Mathematics Project have served as a vehicle for bringing teachers up-to-date with the issues in the current reform movement in mathematics education and for preparing them to provide leadership. During the past 15 years, several documents have been published both at the state and national level, such as *Mathematics Framework for California Public Schools* (California State Department of Education, 1985, 1992) and *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 1989). Through the California Mathematics Project, there developed throughout California a network of teacher leaders, trying to implement changes, as described in these documents, in their classrooms, schools, and districts.

The overall goal of the San Francisco Math Leadership Project is to develop teacher leadership in mathematics education. More specific goals include the following:

- To provide teams of urban classroom teachers with a year-long program that will improve their own mathematical/problem-solving skills, build their confidence, and increase their effectiveness as classroom teachers.
- To provide the participants with ongoing support in two ways: through classroom visits at their school sites and monthly group meetings.
- To facilitate an outreach to other classroom teachers by preparing the participants to share their expertise with colleagues in their schools and district; by providing assistance in the development of workshops; and by funding basic math manipulative materials and resource books for each participating teacher.
- To enlarge the existing nucleus of mathematics leaders in this area by including these participants as active contributors to local conferences, to district inservice programs and to their own schools.

Overall, the San Francisco Math Leadership Project has been quite successful in engaging the enthusiasm of participating teachers and helping them to adopt new teaching methods in their own classrooms. But perhaps more importantly, the participants have emerged as math leaders. This is evidenced by promotions within the district, successful grant writing activities, extensive workshop and inservice education offerings, completion of advanced degrees, and visibility in professional math associations at the local, state, and national levels.

There are many components of this project, some of which will be described in the pages that follow. However, the primary purpose of this chapter is to describe particular aspects of the project that have helped to develop leadership among the participants.

> *After the summer institute I came back to school with a better understanding of what an effective math program should be. I began a new job as a resource teacher, and was able to look at the total school math program. The classes, just like mine had been, were emphasizing computation. I was able to go into classes and do math activities that emphasized other mathematical strands. As a school we focused our inservice efforts on problem solving....In the Fall we did our workshop on Logical Thinking, Measurement, and Estimation. I saw many of our ideas and strategies used in classrooms. I saw an increase in the use of books and math materials that were available in the resource room.*

> *I entered the Math Leadership Project with skepticism. As I participated in the training, I became aware of my own growth in "understanding" math as well as my own learning style... in the fall I took the plunge...The children were enthusiastic and math period lasted 1 1/2 hours daily. Almost half of my students could not do simple computation. They were discouraged and sensed failure. As they succeeded in hands-on tasks and problem solving, their computation skills grew out of an understanding of numbers and necessity. They smelled success....I see their ability and confidence in problem solving with oral and written explanations extending into Social Studies, Science and Language Arts.*

Project Structures Which Promote Teacher Leadership Development

This model for developing math leadership within a school district has three stages. The initial stage is the summer institute, attended by pairs of teachers, with preference given to teachers from the same school. This phase expands the teachers' knowledge of mathematics content and teaching strategies and begins their leadership development. This is followed by the second stage, a year-long program that includes monthly meetings and support for teachers in their classrooms. It is during this year that the teachers begin to feel more like leaders, especially after presenting the required two workshops at their school sites. The next stage of leadership development occurs with the recognition of leadership abilities of these teachers by district personnel. This recognition opens opportunities for these teachers to move beyond their own schools and use their skills on a district-wide level.

Preconference Meeting With Principals

Before the teachers become involved in the program, principals from participating schools are invited to attend an information meeting. This is also a means of informing them about math reform, and serves well as a forum for discussing leadership roles for their teachers. Often, principals describe activities that the teacher leaders have brought to their schools, such as working with parents and teacher aides, designing a math focus for back-to-school nights, school-wide math projects, and an evening devoted to a math fair. They also share creative ways of scheduling math workshops during the year. The need for risk-taking is discussed and principals are urged to encourage the teacher leaders to feel free to take risks in their classrooms, knowing that they might not all work out exactly as planned the first time.

The effectiveness of these meetings is evidenced in the involvement of the principals in mathematics education and in their comments about the program. In the early years, very few San Francisco principals attended local math conferences; currently, there is a strong cadre of approximately 15-20 principals who regularly do so. One principal recently wrote a book chapter in which she shares details about the journey she and her teachers are taking together as they reform their mathematics program (Rosen, 1999). Following are some quotations from letters received from the principals, attesting to the effect of the project on their schools.

> *Through hand-on workshops, conferencing sessions and classroom modeling, they (the teachers who attended the institute) are currently sharing their wealth of knowledge of new expertise with all staff members. The result is a renewed interest and enthusiasm for the teaching of mathematics and problem solving at all grade levels. I am delighted that we have been so fortunate as to have benefited from this project. Most of our teachers have felt limited in their ability to teach*

> *mathematics and are quite receptive to receiving and applying these perspectives and techniques.... The San Francisco Math Leadership Project format is exactly the model needed for teacher staff development in any area. It provides classroom teachers with the opportunity to experience themselves as the knowledgeable professionals they are.*
>
> *As a result of this enthusiasm and their creative approach to the subject there is an increased interest in math throughout the whole school. The two teachers have initiated school–wide math contests, scheduled teacher workshops, and developed a school-wide math and science fair, and by their example made the whole school more math conscious.*

Summer Institute.

The three-week intensive summer institute is a central component of the program. It is designed to allow participants to experience a variety of mathematics teaching strategies that emphasize a problem solving approach to mathematics instruction, the use of math manipulative materials, cooperative group learning, and teaching across the math strands. The institute meets for four full days for each of the three weeks. The participants are surrounded by mathematics. Teachers engage in math activities in the different areas of elementary school mathematics: geometry, measurement, number, patterns and functions, probability and statistics. Problem-solving is emphasized within the content areas and also directly included as a challenging 'Problem of the Day.' This problem is presented as the beginning activity each morning and processed at the end of each day. The teachers receive hands-on experience in working in cooperative groups and in using manipulative materials as tools to solve challenging math problems. They, in fact, become active learners of mathematics and have opportunities to examine their feelings as they assume active roles in their own learning.

Because an integral part of the project is the development of math leaders, a key aspect of the institute is the opportunity for participants to practice developing and delivering workshops utilizing innovative math instruction. During the final week of the institute, participants develop and give such a presentation to their peers. By committing to this project for one full year, the participants receive a stipend, course credit, manipulative materials and resource books for teaching mathematics.

Academic Year Activities.

During the year following the summer institute, the teachers attend monthly meetings that provide the opportunity for mutual support and sharing of ideas. These meetings have been a constant feature of this project since its inception in 1984 and continue to this day. Some of the meetings are three hours long and held after school; a few of the meetings are scheduled for a full day with substitute teachers paid through the project. Often these meetings are held at the teachers' school sites. The teachers enjoy visiting each other's schools and classrooms and obtain many ideas from seeing the different environments. For each meeting, we ask the teachers to try out lessons in their classrooms with a specific math content focus and to bring children's work to share at these meetings. They benefit from the opportunity to share their successes as well as their challenges. At each meeting there is at least one math activity as well as reflection and discussion of the workshops that teachers have given at their schools.

Since 1991, teachers have been expected to keep a portfolio of student work done during the school year. They are asked to write a reflection page on 8-10 lessons and include samples of student work for each lesson. These portfolios show the range of topics introduced to students and the thoughtfulness of the teachers as they think about ways to improve their lessons. These reflections on their own practice are also very useful to the teacher leaders when they are presenting their own workshops. Using anecdotes about their own experiences enhances their workshop and brings credibility to the presentation.

During the year following the summer institute, the teachers are also required to present two workshops at their school sites and to attend a math conference. In May a celebration dinner is held for all math leadership teachers with special recognition for the current cohort of teachers.

Over the years teachers have received classroom support from the project in a variety of ways. Sometimes, past participants, who for various reasons are on leave from their regular teaching responsibilities, are hired by the project to visit these teachers. They often teach special lessons, or help the teachers to plan and teach a particular lesson, or observe the teachers and give them feedback. The teachers generally felt very supported by visits from persons in a non-supervisory role.

There have been many different types of during-the-year activities aimed at continuing the network of teachers who have participated in earlier years. These have included grade-level planning groups for past participants, organized and led by teacher leaders and a variety of annual reunions. Some years, two or three-day retreats away from usual surroundings have provided the setting for the reunion. The summers have also provided time for one-unit mini-courses in geometry, measurement, teaching algebra through the grades, and introductory probability. Sometimes these mini-courses were offered during the school year on weekends. Most recently a very successful one-day Saturday session was provided for teachers to learn to use the Internet.

During the years 1991-1994 an advanced component, referred to as Level II, was developed to respond to the needs of teachers who had participated in past years and expressed an interest in learning more mathematics. As a result, sixty-two teachers participated in a yearlong program that included a one-week summer institute with a focus on mathematics content in the areas of geometry, measurement, and probability and statistics. There were four full-day meetings during the school year.

The leadership development of the teachers begins during this first year of participation in the project when they increase their math content knowledge, experience a variety of teaching strategies and reflect on the ways that they themselves, as well as their students, learn mathematics. This contributes to a renewed interest in and enthusiasm for the teaching and learning of mathematics that enhances their credibility as they begin to take on leadership roles. Their presentations during the final week of the summer institute along with the two workshops that they present at their school sites also play a large part in helping the teachers recognize their own potential for leadership.

Changing Teachers' Mathematical Understanding

The math content pre-test, given on the first day of each summer institute, is perhaps the least favorite activity of the participants, because it reminds them of the anxiety many still have concerning mathematics. This test serves to illustrate the areas that require the most attention as well as a means for determining where participants have made the most gains by the end of the institute. The basic mathematics concepts on this test are an important part of the mathematics curriculum for the elementary grades. Of the 24 items on this test, more than 30 percent of the 97 participants during the years 1984-87 missed items relating to topics such as: finding areas of regular and irregular shapes; statistical terms (mean, median, mode); simple probability; locating coordinate points on a grid. Many teachers were also unable to recognize the formula for the area of a square or to convert a decimal to a percent.

A comparison of the results of the post-test, which is given on the final day of the institute, with the pre-test, showed that most of the teachers' scores had improved. Many teachers found that they could approach the problems in different ways and could think about them more carefully.

> *When I entered your project I expected instruction and materials to help me teach fourth grade math. I did not expect to gain an interest, a curiosity, a confidence, and an eagerness to acquire more mathematical experience. I did not expect to become a questioner, 'Have you tried this?' 'How do you teach that?'...I find, because of this experience, teaching and learning mathematics has become a great pleasure. ...For me, the most important effect of the Math Leadership Project has been the wonderful realization that thinking and trying are the basics of mathematics. The idea that diverse methods of inquiry are acceptable and valid. That one has nothing to lose by attempting many ways to come to a conclusion.*

They reported that at the very least they made a thoughtful attempt to solve the problems and were able to tell if their answers made sense. Table 1 presents a comparison of pre- and post-test scores for participants during the years 1984-1987. Learning mathematical content continues to be a major emphasis of this project and an essential ingredient for leadership in this area.

Self-evaluation of classrooms.

Teachers were asked to complete a self-evaluation of their own classroom practices prior to the summer institute and also at the end of the first year in the project. The data provided in Table 2 illustrates the results from the pre-post self-evaluations for the years 1987-1993. The areas of the biggest challenge for teachers were in the application of problem solving and thinking skills and having a sufficient variety of math activities available for student use.

Table 1
Results of Math Test, 1984-1987

Project Year	Pre-Test	Post-Test	Significance
1984 (n=24)	$\bar{X} = 19.51$	$\bar{X} = 20.5$	$t = 1.1909$
1985 (n=19)	$\bar{X} = 15.90$	$\bar{X} = 17.7$	$t = 1.083$
1986 (n=25)	$\bar{X} = 16.90$	$\bar{X} = 19.0$	$t = 1.371^{*}$
1987 (n=28)	$\bar{X} = 14.50$	$\bar{X} = 17.5$	$t = 3.047^{**}$
Combined (n=96)	$\bar{X} = 16.60$	$\bar{X} = 18.7$	$t = 3.044^{**}$

Note. From "Making Math Leaders: The San Francisco Math Leadership Project," by Carol R. Langbort,1990, *School of Education Review*, *2*, p. 51. Copyright Spring 1990, by San Francisco State University.

$\bar{X}$ = mean score for number correct based on a total of 24 questions
*$p<.10$
**$p<.01$

Even after only one year, it is apparent that significant changes occurred in two major areas: increased versatility in the classroom and a strengthened learning component. In the area of classroom versatility, teachers reported that they were using varied strategies to teach computing skills, providing for differences in children's learning styles, and balancing the content among the different areas of mathematics. They also reported using a variety of math activities. In the learning component, teachers reported using manipulative materials to reinforce concepts, developing concepts from concrete to pictorial to symbolic, using activities that promote success, challenging children and encouraging divergent thinking and multiple approaches. Many of these approaches were used in the summer institute and the teachers were able to transfer them to their own classrooms. Many teachers described changes that they had made in their classrooms on an end-of-the-year evaluation. Following are one teacher's remarks.

Table 2

Teachers' self evaluation of their own classrooms

	1987 n = 25 Pre	1987 n = 25 Post	1988 n = 35 Pre	1988 n = 35 Post	1989 n = 39 Pre	1989 n = 39 Post	1990 n = 41 Pre	1990 n = 41 Post	1991 & 1992 n = 44 Pre	1991 & 1992 n = 44 Post	1993 n = 30 Pre	1993 n = 30 Post
I. CLASSROOM ATMOSPHERE												
a. Atmosphere is positive and conducive to learning	2.2	2.1	1.9	1.4	2.1	1.4	2.7	2.4	2.0	1.5	2.2	1.8
b. Teacher has high expectations	1.8	1.8	1.7	1.6	1.8	1.5	2.1	1.8	1.8	1.6	2.0	1.6
c. Teacher is enthusiastic	1.8	1.7	1.6	1.5	1.8	1.3	2.3	2.1	1.6	1.5	1.8	1.5
d. Structure builds confidence	2.2	2.2	2.1	1.9	1.9	1.9	3.0	2.3	2.4	1.5	2.3	1.7*
e. Thinking is encouraged	2.1	2.0	1.9	1.7	2.0	1.7	2.2	1.9	2.2	1.4*	2.2	1.5*
f. Students are grouped in variety of ways	2.5	2.1*	2.7	2.5	2.5	2.3	3.0	2.2	2.7	1.3*	2.4	2.0
g. Children's work in evidence	2.3	2.0	2.1	2.0	2.3	2.1	3.0	2.2	2.2	1.8	2.3	1.8*
II. CLASSROOM VERSATILITY												
a. Varied strategies are used to teach computing skills	3.0	2.2***	2.8	2.2	3.0	2.3	3.3	3.4	2.7	1.5*	3.0	2.4
b. Equal time given to mathematics	2.8	2.0**	2.7	2.0	2.7	2.5	2.9	2.5				
c. Teacher provides for differences in students' learning style	3.0	2.4**	2.7	2.5	3.0	2.3	2.7	2.4	2.7	2.1	2.8	2.0*
d. Variety of math activities are available for students use	2.9	2.1***	2.9	2.1*	2.9	2.1*	3.7	2.3**	2.7	1.6*	3.2	2.0*
e. Overall content is balanced	2.9	2.2**	3.0	2.9	2.9	2.2	2.9	2.6	2.7	2.0	3.1	1.6*
III. PROBLEM SOLVING AND THINKING												
a. Emphasis on application in computing	3.0	2.4	2.9	2.4	2.9	2.3	3.0	2.6	3.1	2.2*	3.2	2.4*
b. Process as well as product articulated	2.8	2.4	2.8	2.4	2.8	2.4	2.9	2.5	2.8	1.7*	3.0	1.8*
c. Problems are formulated and analyzed	3.1	2.8	3.2	2.7	3.1	2.4	3.2	3.1	3.2	2.1	3.3	2.2*
d. Students are encouraged to estimate and hypothesize	3.0	2.1***	3.0	2.2	3.0	2.2	2.8	2.3	2.9	2.5	3.1	2.2
e. Teacher has a problem-solving plan	3.4	3.3	3.6	3.0	3.4	2.3	3.2	2.7	3.3	2.2*	3.4	2.2*
f. Problems are used that have many right answers	3.4	3.0	3.5	3.0	3.4	2.4**	3.4	3.0	3.3	2.5	3.4	2.6
IV. LEARNING COMPONENT												
a. Manipulative materials are used to reinforce concepts	2.5	1.7***	2.6	1.8	2.6	1.4**	3.2	1.8*	2.3	1.6*	2.8	1.6*
b. Concepts are developed from concrete to pictorial to symbolic	3.0	2.3**	2.8	2.0	2.9	1.8*	3.0	2.5	3.0	2.1	3.3	2.1
c. Activities are used that guarantee success	2.8	2.0***	2.8	2.2	2.8	2.0*	3.5	2.4*	2.8	1.5*	3.5	2.2*
d. Many approaches and divergent thinking are encouraged	2.8	2.1**	2.8	2.1	2.8	1.7*	3.3	2.2*	2.6	2.0	3.4	2.0
e. Children enjoy math sessions	2.3	1.6**	2.7	1.8*	2.5	1.7*	3.2	2.3*	2.9	2.1	2.8	1.9
f. Children are challenged	2.4	1.9**	2.6	1.7*	2.5	1.6*	2.7	2.1*	2.6	1.2*	2.9	2.2
g. Children are writing in the math classroom.	--	--	--	--	--	--	--	--	3.2	1.6*	3.0	2.2

Scale: 1-2 = excellent; 3 = good; 4-5 = needs more focus; *p<.05; **p<.01; ***p<.001

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> *I think the major impact from my Math Leadership experience is the way I've taught math concepts. For example, problem solving was a language arts journal activity. I modeled problems using the children's names in the problem, which created more interest, writing it on the board. We read it together. We talked about whether we would add or subtract, should the answer be larger or smaller, etc. The class would read the problem, discuss it, write the math equation sentence, draw and illustrate the answer and finally act it out. We did this on a regular basis for weeks. The children would come up with their own problems, which really meant that they understood the concept and utility of adding or subtracting numbers. I have incorporated a lot of writing and processing which I would not have done previously.*

Both content and pedagogy are essential in this Project and they are integrated as teachers learn or relearn mathematical concepts through a variety of pedagogical methods. Most of their own school learning of mathematics centered on memorizing rules and procedures with little chance for real understanding. Teachers reflected on their own learning through a variety of methods and recognized that some methods were preferable to them, while others preferred different methods. This process contributed to their effectiveness with their own students as well as their effectiveness in leadership roles.

Leadership Development

Leadership development is the central focus of the next section, where detailed information is presented about presentations at summer institutes, workshops at the teachers' schools, and the variety of leadership activities undertaken by these teachers.

There are two closely related components of the Project which are crucial to the leadership development of the teachers. The first occurs during the summer institute when the teachers must plan a presentation for their peers. The second is the requirement that they present two workshops at their school sites during the year. These components were part of the original project fifteen years ago and have continued to the present. Developing presentation skills within a supportive environment is a major factor in assisting these teachers to view their own potential for leadership.

Summer institute presentations.

Giving a presentation during the last week of the summer institute seems to be 'trial by fire' for many of the teachers. Most of the participants are nervous about this event. Two afternoons of the second week are devoted to preparation, and then, the actual presentations fill most of the slots during the final third week. The week is set up like a mini-conference, with a program of titles and speakers prepared in advance. Planning and presenting in pairs helps to alleviate some of the teachers' nervousness and provides an opportunity for pairs of teachers from the same school to work closely together.

By the time that teachers start planning for their sessions, they have already been involved in eight full days of workshops on a variety of topics. During these experiences the teachers are always trying to increase their knowledge of the mathematics while at the same time experiencing different models of presentation. These experiences give the teachers the opportunity to carefully consider the workshop elements that they like or dislike. Therefore, the first session on workshop preparation is devoted to brainstorming attributes of workshops: those items that contribute to the success of a workshop and should be included, and those that detract from it and should be avoided. Teacher participants from past years are given a leadership role as they are invited to return for the workshop presentation time to give assistance and advice to small groups of teachers as they plan their presentations.

Additional support is provided through resource books which aid the teachers in developing ideas that would be useful to them in this endeavor. With these resources, the teachers looked for activities and ideas that had not been presented in the previous two weeks. Teachers usually highlighted connections between specific aspects of the activities and the reform documents. Often the workshops reflected the bigger picture of mathematics reform. Knowledge about reform and ways to bring that back to their schools enhances the teachers' leadership skills. The teachers also work to include activities appropriate for several grade levels. Knowledge of the development of concepts across several grades enhances the workshop when the teachers present it at their school sites and also contributes to their development as leaders.

There is excitement in the air during the final week of the institute when most of the time is devoted to teachers' presentations.

And the presentations are characteristically quite professional and memorable. A special evaluation form was developed and is completed immediately following the presentation. The evaluation form queries about the content of the presentation, including the appropriateness, interest level, and difficulty level. Respondents are also asked to write about what they liked about the way the presentation was conducted and offer suggestions for improvement. Additional questions ask for any problems that the leaders could anticipate with an audience of teachers and any comments which would be helpful to the presenter. The audience completes this form immediately following the presentation. These are then returned to the presenters. During the final fifteen minutes of the presentation, the audience gives oral feedback to the presenters with a focus on the positive aspects of the session.

The presenters also fill out a self-evaluation. Presenters fill this out following their presentation. The questions include asking the presenter what they learned about organizing a presentation, what they would do differently in designing their next workshop, what worked, how it felt to plan together, and what would improve the process. The comments are used in subsequent years to assist others in preparing their presentations. These comments are often utilized during the introductory session on presentation preparation the following year. Giving this presentation seems to be a critical experience for the teachers. Many lack confidence in their ability to speak in front of adults and feel some insecurity in their ability to answer questions. Once they pass this milestone, they seem to increase their confidence and their leadership development is well under way.

Workshops at school sites.

During the school year following the institute, the teachers are required to give two workshops to teachers at their school sites. They need to make scheduling arrangements with their principals early in the school year, for often these workshops are scheduled as part of a faculty meeting. The teachers are encouraged to pair up to give these workshops. Often, the teachers are teaching different grade levels and are able to present an idea or topic that is appropriate across grade levels with each teacher presenting materials for their particular age group. The teachers are encouraged to try the activities with their own students prior to the workshops, so they can bring classroom anecdotes and students' work to share with the teachers. During the summer institute, it was stressed that the teacher leaders did not need to be the final expert on a topic; the workshop was a way to share their experiences with their colleagues. This seemed to help alleviate some of their anxiety.

Most of the teachers are quite pleased with their presentations and with themselves. The event is generally more enjoyable than they had anticipated, and many find that they actually enjoy giving workshops. As a result, they easily became the math resource person at their schools; they are often asked for materials, suggestions for resource books, and were looked to as someone with a little more expertise in teaching mathematics. Two teachers expressed their thoughts about their new leadership roles:

> *My confidence as a math teacher has certainly grown and other teachers at my school are beginning to look to me as a resource. I find myself much more interested and eager to teach what I once considered beyond me.*
>
> *Giving workshops to other teachers helped me grow as a teacher. I was excited to share as much as I could. My neighboring 5th grade teacher used the "Seeing Fractions" unit with her class. I felt great as I saw her proudly display their work.*

Over the years, many letters have been received from principals following these workshops. They are most complimentary and truly appreciative of the quality of the workshops and the enthusiasm of their teacher leaders.

> *Both teachers have shared materials ordered through your program with other teachers on site. As a result of their renewed math enthusiasm, other teachers have requested like manipulative materials for classroom use. ...As a result of the workshops, there is renewed enthusiasm on the part of teachers and students school-wide.*
>
> *Our 5th grade teacher has given one inservice to the faculty which has been extremely worthwhile, informative, enthusiastic and well-done. I have seen how this has inspired and helped this teacher in the teaching of math in her class and her enthusiasm and expertise has inspired others...*

The project has essentially provided school principals with one or two teachers who are knowledgeable, interested and enthusiastic about teaching mathematics. In addition, the principals have teachers to whom they can turn, to whom they can direct information about mathematics or recommend for district committees. Tenets of the reform movement in mathematics are thus brought to many schools in this way.

Leadership roles.

The leadership potential of project teachers is tapped with the completion of this first year. Following this experience, additional leadership opportunities must be provided to continue the growth and development of these teacher leaders. During the early years of the project, university professors designed and taught in the summer institute. After a few years, however, teacher leaders began emerging and formed a team of instructors which has lasted for many years. Each summer, a core of five to seven teacher leaders forms the team who plans and teaches in the summer institute. Additional teachers are invited back to give guest presentations on particular topics as well. Although some teachers have moved to positions outside the classroom, most often as principals or teachers on special assignment in the district office, the focus of this project is the classroom teacher and their leadership roles while they are classroom teachers.

Classroom teachers can exhibit leadership in a variety of ways. Several teacher leaders have written and received grants. Some of these grants provided funds for staff development at their sites; others provided money to buy manipulative materials for their classrooms or schools. A few teachers from different schools joined together to write a grant to support the development and presentation of math fairs at their schools. Two teacher leaders wrote articles for publication. "Designing Math Fairs" was published in the ComMuniCator, the journal of the California Mathematics Council (Schneider, 1990) and "Assessing Measurement in the Primary Classroom" was published in the National Council of Teachers of Mathematics 1993 Yearbook *Assessment in the Mathematics Classroom* (Sanford, 1993).

The school district has also provided leadership opportunities for our teachers. They have been asked to give workshops at schools not involved in the project and to develop short institutes with a particular content focus. One district sponsored a 4-Saturday Geometry Institute for teachers of grades 4-8, which was planned and taught by teachers from this project. Over the years, the teacher leaders from this project made up a large percentage of the pool of teachers from which district committees were formed: some served on textbook selection committees, math curriculum development committees, Standards Writing Committee, and Assessment Item Writing Committee.

San Francisco Math Leadership teacher leaders played a pivotal role in an enormous undertaking by the San Francisco Unified School District. These teacher leaders provided professional development in mathematics over a three-year period (1994-1996) for all elementary teachers as support for implementing recently adopted curriculum materials. During this project 150 teachers were prepared to present workshops for the teachers from 76 elementary schools. Many project teachers were on the district team which designed and implemented this inservice program, and provided the professional development for the workshop leaders. Many others presented workshops in the schools.

Some teacher leaders have become regular speakers at local and state-wide math conferences. They have been appointed to state-wide committees involved in writing frameworks, or working on designing assessments. Several have been appointed as district math coordinators. One group of teachers planned and implemented a 20-hour professional development series with a focus on number sense for a group of 30 teachers from several local school districts.

Although there already existed in San Francisco one organization for math teachers, focused mainly on high school teachers, in 1989 a group of Math Leadership teacher leaders formed a new organization for teachers, the San Francisco Math T.E.A.M. (Teachers of Elementary and Middle School). This became an affiliate of the California Math Council and has organized several local math conferences. Even today, ten years later, the organization still exists, the officers are still Math Leadership teachers, and they continue to hold regular meetings and provide support for veteran and beginning teachers.

Perhaps the most important leadership roles occur at the school site on a day-to-day basis. Thirty-two respondents to a 1993 survey sent to project teachers in a subset of San Francisco schools provided information regarding their leadership activities at their sites. These teachers represented fourteen schools and had participated in the project during the years 1985 through 1992. Table 3 provides a summary of the extent to which these teachers have made an impact on their own schools. One teacher made the following comment:

Table 3. Teachers' Leadership Activities

Activity	Number	Percent	Range
Been asked by Another Teacher How to Teach a Math Concept	32	100%	4-50 times
Been Asked to Visit Another Teacher's Classroom to Observe And Give Feedback	13	40%	1-6 times
Been Asked by Another Teacher to Teach a Certain Concept or Demonstrate a technique	20	63%	1-50 times
Developed a Special Math-Related Event at Your School	20	63%	1-10 times
Organized Informal Discussions About the Teaching of Mathematics With Other Teachers in School	6	50%	2-50 times
Contacted or Met with Other SFML Teachers Outside Regularly Scheduled Meetings	17	53%	2-20 times
Used Computer Software to Teach Math	20	63%	'once' to 'daily'
Written a Grant Proposal to Improve Math Teaching	12	38%	'once' to 'twice'
Given an Inservice Workshop For Other Teachers on Math Education	15	47%	1-20 times
Presented a Workshop at a Local, State, or National Association Professional Meeting	4	13%	1-3 times
Published an Article on Math Education	2	6%	1 each, in progress

N=32

Note. Adapted from *Results of Follow-up Questionnaire to Participants of San Francisco Math Leadership Project who are Teachers in Consent Decree Schools*, by Patricia M. Armstrong, Ph.D.1993.

> *I do believe one of the biggest changes is in the area of working with other teachers. I am trying to reach out and help others find different or new ways to present math in their classrooms.... Teachers are beginning to ask for materials, suggestions and want to work as a team.*

Of the 11 activities listed, the majority directly impacted the lives of teachers and children at the school sites of the teacher leaders. Additionally, participants have been particularly active in the development of school-wide math events, including presenting workshops for parents, designing math fairs for parents and children (Schneider, 1989), developing a hands-on math lending library, and writing grants to purchase manipulative materials. Grant awards have ranged from $100 to $5000. Many of the leadership roles taken by teachers in the San Francisco Math Leadership Project provided examples for those described in the Mission Statement of the California Mathematics Project (1990). These are presented in Table 4.

Concluding remarks

One of the important things we learned about leadership development and the improvement of math teaching is that it takes time. The first year of active participation in the project is only the beginning. The networking that the project provides and the close ties that the teachers develop with teachers at different schools contributes to leadership development and support. The summer institute, where the teachers become enthusiastic about learning and teaching mathematics lays the foundation for their future work. When they return to their classrooms and teach math in new ways, they become excited about teaching and are building a repertoire of activities, and collect children's work and anecdotes that they will be able to share with others. The presentations that they give during the summer institute along with the workshops that they give at their schools help develop a new level of confidence that supports their new roles as teacher leaders. Many of the changes in classroom teaching and, concurrently, the changes in teachers' views of themselves as leaders emerge several years later.

The project opens the door for each teacher to become a professional. All have attended at least one major math conference during the first year of the project. For many teachers this is the first math conference they have ever attended. After attending a few conferences, they become confident in their own ability to speak

Table 4. Teacher Leaders

Who are Teacher Leaders?

A teacher leader in mathematics may be one who:

- fully implements a rich mathematics program in the classroom, setting an example for colleagues.
- tries new assessments in the mathematics classroom and shares the experience with the teacher next door.
- conducts ‘beyond the bells’ activities for mathematics students such as mathematics study groups, homework hotlines, mathematics clubs, mathematics teams, mathematics fairs, etc.
- works to provide resources at the school level, thereby raising the level of support for the mathematics program in the school.
- becomes a mentor teacher in mathematics, helping other teachers to improve mathematics instruction.
- serves on committees and works toward meaningful school/district mathematics improvements in the mathematics program.
- connects to the larger network of teachers seeking improvement in mathematics learning and encourages other teachers to become actively involved.
- becomes involved in the leadership of NCTM, CMC, or a local affiliate by serving as an officer or committee member.
- contributes to the leadership of a Mathematics Project as a site director, co-director, mentor or continuing active worker.
- connects to state or national staff development projects and committees helping to lead the effort and encouraging colleagues to take part.
- gets involved in a curriculum project helping to develop, pilot and evaluate new mathematics materials.
- participates in state or national assessment programs helping to design, score, and evaluate new mathematics assessments.
- learns a new technology, uses it in the classroom, and helps other teachers to use it.
- works with diversity/equity programs to make mathematics accessible to all students.
- works to bring more teachers of color into the effort to improve mathematics teaching and learning.
- learns techniques of teaching English language learners and works to apply these techniques to mathematics teaching.
- develops skills for presenting to colleagues and shares knowledge and experiences at mathematics meetings, workshops, institutes, etc.
- becomes a spokesperson for improving mathematics learning and makes presentations to school administrators, school boards, parents, community groups, government and the media.

Note. Adapted from the Vision Statement of the California Mathematics Project, 1990.

at a conference and team up with another teacher leader to present a workshop. By attending conferences each year they continue to grow in the area of mathematics education. Becoming a professional, first by joining organizations and attending conferences and then by serving on committees, becoming officers, organizing conferences and speaking at them, contribute to the development of leaders.

Leadership development requires time and it also takes various forms. All teachers who have participated in this project have given the two required workshops at their own school sites; many have continued to give workshops. Some, but not all, become interested in working with other schools, expanding their workshop repertoire and taking on an even greater variety of leadership roles. Others prefer to take on a variety of leadership activities at their own sites, such as those described in Table 3.

The district is not the only beneficiary of this work. The teacher preparation program at the university has also benefited. We have access to model classrooms in which to place credential students, both for observation and for their student teaching experiences. Several teachers have been appointed adjunct professors, teaching the math methods course for preservice teachers. Some project teachers who have retired from classroom teaching have returned to the university to supervise student teaching. One teacher recently earned her doctorate and is currently teaching methods and graduate level courses. Several others have earned masters degrees, with a concentration in mathematics education, in a new program specifically designed for classroom teachers (Langbort, 1998). Leadership takes a variety of forms, many of which cannot be predicted at the outset of an undertaking such as this Project. It is also difficult to predict which teachers will take on substantial leadership roles. It is important, however, to recognize the leadership potential in all the teachers, to encourage leadership in a variety of forms, and to reward those who do expand their professionalism in this way. Two teachers have summed up the impact of their experiences in the San Francisco Math Leadership Project in the following quotations:

> *It was very difficult for me to leave the text and venture into the unknown. The preparation was sometimes staggering, the timing sometimes off, and the room sometimes messy, but the results can be summed up by one of my parents who said, "my daughter is no longer afraid of math." That's it! That is what we're trying to achieve.*

> *Over the years I have turned toward the math textbook as my main vehicle for teaching mathematics. Through the last eight years, as I observed my colleagues who had attended Math Leadership, I was impressed with the materials these teachers shared with the staff at workshops....I noticed their classes were lively and interesting. Their students were engaged, enjoyed teamwork, and worked on long–range projects with great interest.... I needed new life in Math...A highly respected colleague told me Math Leadership would be a life-altering experience. After the training and exposure to the talented, lively staff (all women) for a year, I must admit I see changes and improvements in my approach to teaching Math....I am much more open to new ideas. I prepare new lessons, which the students really like. They no longer have to face my former 'turn to page 56' mentality. I am having fun experimenting with totally new concepts and lessons. Often I feel nervous now that I have left the boring path to Math. It is exciting. My enthusiasm is contagious. My students are comfortable working with most word problems....There is so much more to study and enjoy."*

References

(1992). *Mathematics framework for California public schools (K-12)*. Sacramento: California State Department of Education.

Armstrong, P. M. (1993). *Results of follow-up questionnaire to participants of San Francisco Math Leadership Project who are teachers in consent decree schools*. San Francisco: San Francisco State University.

Langbort, C. (1990). Making math leaders: The San Francisco Math Leadership Project. *School of Education Review* 2(Spring): 48-54.

Langbort, C. (1998). Developing teacher-leaders in a master's degree program in mathematics education. *Mathematics and Education Reform Newsletter* 11(Fall): 4-6.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston: Author.

Rosen, J. (1999). Requirements for change. In M. Burns(Ed.), *Leading the way: Principals and superintendents look at math instruction*,67-80. Sausalito: Math Solutions Publications.

Sanford, S. (1993). Assessing measurement in the primary classroom. In N. L. Webb (Ed.), *Assessment in the mathematics classroom* (pp. 74-79). Reston: National Council of Teachers of Mathematics.

Schneider, C. (1989). Math fairs-inservice while students learn. *CA Math Council, ComMuniCator*, 13(4), 18-19.

14

Evaluation of Teacher Leader Professional Development Programs

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This chapter outlines the considerations necessary in planning and conducting evaluations of teacher leadership programs. It contains a discussion of different definitions of evaluation, their underlying philosophies and their importance for teacher leadership programs. Specific ideas for conducting teacher leadership program evaluations are presented. These include: evaluation of the delivery of professional development programs, effects on teacher leaders, effects on classrooms and students, effects within schools, and effects within districts and states. Suggestions include both qualitative and quantitative approaches and examples are provided from existing teacher leadership programs. The Horizon Research Inc. forms for classroom and professional development observation are described in some detail.

The purpose of this chapter is to outline the considerations necessary in planning and conducting evaluations of teacher leadership programs. The chapter begins with a look at the various definitions of evaluation and their relationships to different evaluation philosophies. Next the importance of evaluation for teacher leadership programs is discussed. After the introductory sections, specific ideas for conducting evaluations to determine effects of teacher leader programs are presented. These evaluation methods are grouped under different types of effects and include evaluation of the delivery of professional development programs, effects on teacher leaders, effects on classrooms and students, effects within schools, and effects within districts and states.

What is Evaluation?

The Joint Committee on Standards for Educational Evaluation (1994) defines evaluation as the systematic investigation of the worth or merit of an object. Objects include educational and training programs, projects, and materials. Michael Scriven in his *Evaluation*

Thesaurus (1991) agrees with this definition and goes on to say that the process normally involves: "some identification of relevant standards of merit, worth, or value; some investigation of the performance of evaluands on these standards; and some integration or synthesis of the results to achieve an overall evaluation" (p. 139). One of the first definitions of educational evaluation was provided by Daniel Stufflebeam and the Phi Delta Kappan National Study Committee on Evaluation in *Educational Evaluation and Decision-Making* (1971). In this book the authors say "the purpose of evaluation is not to prove but to improve" (p. v). They define evaluation as the systematic process of delineating, obtaining and providing useful information for judging decision alternatives. This definition is particularly useful in that it highlights that evaluation includes determining what type of information should be gathered, how to gather the determined information and how to present the information in usable formats.

Michael Quinn Patton in his book *Utilization-Focused Evaluation* (1997a) reiterates and expands on the notion of usefulness by making it clear that the receivers of the evaluation information need to be substantively involved in the evaluation process so that the resulting information will be used effectively. A recent addition to the definitions is David Fetterman's (1996) empowerment evaluation. There has been considerable debate about this approach. Fetterman (1997) describes empowerment evaluation as a shift from the previously exclusive focus on merit and worth alone to a commitment to self-determination and capacity building. In other words, empowerment evaluation is evaluation conducted by participants with the goal of continual improvement and self-actualization. Patton (1997b) places empowerment evaluation into a larger context of emancipatory research and goes on to say that teaching evaluation logic and skills is a way of building capacity for ongoing self-assessment. Emancipatory research is the process of using research to improve the researcher and provide the capacity for even more sophisticated self-knowledge and self-determination.

How are the Definitions of Evaluation Related to Evaluation Philosophies?

The different definitions and models for evaluation are based in different philosophies. House (1983) has categorized these differing philosophies along two continua: the objectivist-subjectivist epistemologies and the utilitarian-pluralist values. Objectivism requires evidence that is reproducible and verifiable. It is derived largely from empiricism and related to logical positivism. Subjectivism is based in experience and related to phenomenologist epistemology. The objectivists rely on reproducible facts while the subjectivists depend upon accumulated experience. In the second continuum, utilitarians assess overall impact while pluralists assess the impact on each individual. In other words, the greatest good for utilitarians is that which will benefit the most people while pluralism requires attention to each individual's benefit. Often utilitarianism and objectivism operate together and pluralism and subjectivism operate together although other combinations are possible. These combinations lead to a wide variety of evaluation approaches and methods. Given the definitions above, Scriven and Patton would be in the middle of the road; Fetterman would be nearer the subjectivist and pluralist poles; and Stufflebeam would be nearer the objectivist and utilitarian poles.

Another elaboration on evaluation is necessary. Although there are many similarities, evaluation and research are not the same and their uniqueness should be kept in mind. Worthen, Sanders and Fitzpatrick (1997) describe the distinction quite well. They point out that evaluation and research differ in the motivation of the inquirer, the objective of the inquiry, the outcome of the inquiry, the role played by explanation, and in generalizability. Evaluators are almost always asked to conduct their evaluations and therefore, are constrained by the situation. However, although researchers may apply for grants to conduct their research, they are generally the ones that make the decisions about why and how to conduct it. The objectives and outcomes in the two types of inquiry are also slightly different. Research is generally conducted to determine generalizable laws governing behavior or to form conclusions. Evaluation, on the other hand, is more likely to be designed to provide descriptions and inform decision making. Finally, evaluation is purposefully tied to a specific object in time and space while research is designed to span these dimensions. These distinctions are important because they affect the type and appropriateness of evaluation designs. Because of their tie to specific situations, evaluations are both less and more constrained than research. They are less constrained because they do not have to be universally generalizable, but they are more constrained because they have to fit into a specific context.

Each of the different approaches to evaluation has its own strengths and limitations, so careful selection of approaches is critical

(National Science Foundation, 1997). Approaches need to be tied to the uses that will be made of the evaluation information by the various audiences. In teacher leadership programs there are many different audiences for evaluations. A potential list includes: the teacher leaders themselves, the people running the professional development programs, the classroom students of the teacher leaders, the colleagues of the teacher leaders, the schools and districts in which the leaders work, the state and national organizations interested in professional development and student learning, and agencies funding the programs. Each of these audiences has its own special information needs and may respond differently to different types of evaluative data. An evaluator should identify these needs, preferences and potential responses as the evaluation is being planned so that the resulting data will be used most effectively. Thoughtful analysis, sensitivity, common sense and creativity are all needed to make sure that the actual evaluation provides information that is useful and credible (Stevens, Lawrenz & Sharp, 1993).

Why is Evaluation Important for Teacher Leadership Programs?

Evaluation can meet several needs in the professional development of teacher leaders. First, evaluation can provide information that helps to justify the program. This type of information is of most interest to program planners and to program funders. In Stufflebeam's (1971) CIPP (Context, Input, Process and Product) model this type of evaluation would be in the context and input realms. The evaluator would be determining what the needs are for a program of this type among the constituents, which would guide the choice of objectives and assignment of priorities (context evaluation). Additionally, given the constraints and opportunities in the situation, the evaluator would be determining what mechanisms would be most feasible (input evaluation). Although both of these types of evaluation can be used in summative and formative fashions, these generally are formative in nature. They help a program decide what to do and how to do it. Another way to think about these types of evaluation is to envision them as checking on the logical contingencies of the program plan (Stake, 1968). In other words, is it logical to expect that the procedures the program is proposing will produce the desired outcomes given the potential participants? Typical questions are:

1. What needs are there for this program?
2. Who are the stakeholders?
3. Are the goals appropriate?
4. What is the best way to accomplish the goals?
5. Will these procedures fit within the situation?
6. Given these potential participants, should these procedures be effective?
7. Is it logical to expect these outcomes after treating the participants in these ways?

Another reason for evaluation is accountability. This type of evaluation is generally both summative and formative. A summative evaluation approach helps program planners know if they are accomplishing their goals. This demonstrates if the program is successful or not to various stakeholders. A more formative approach would be determining strengths and weakness in the program or the leaders it produces. This type of information helps the program to improve itself. Accountability information can be both process and outcome oriented. In terms of process, an evaluator can examine how a program operates, how its procedures combine, and how effective they are. In terms of outcome, an evaluator can determine the effects of the process on the teacher leaders. Typical questions for summative and formative evaluation are:

1. Are they doing what they said they were going to do?
2. Are effective management structures in place to support teacher leaders?
3. Are communication channels open and operating between teacher leaders, teachers, and school administration?
4. Are goals understood and shared by all?
5. Are the presenters in the professional development sessions well qualified?
6. Are the sessions well planned?
7. Do the participants believe they have benefited from the sessions?
8. Do the participants expect to change their behavior?

9. Has the behavior of the participants changed?
10. Have other teachers or students benefited from the changed behavior of the participants?
11. Have schools been affected?

Finally, effectively used program evaluation can instill in the teacher leaders belief in the usefulness of evaluation. The outcome of evaluation is enhanced by the inclusion of empowerment evaluation techniques where the participants in the program are intimately involved in the evaluation effort. Participant involvement with the process of evaluation helps to align the goals of the evaluation with the goals of the teacher leaders. It also provides teacher leaders with evaluation skills to use in other settings. In other words, substantial involvement in evaluation of the professional development program is an excellent opportunity for extending the professional development of the teacher leaders. In order to accomplish this, the teacher leaders must be given the power to determine at least part of the evaluation effort. Teacher leaders should specify program goals they value and determine what data needs to be gathered in order for them to decide if the program has been effective in meeting its goals. Involvement in goal formation helps to make teachers more committed advocates for the program and provides more in depth understanding of program goals. Teacher leaders also need to be involved in data gathering efforts so they will better understand the relationships between goals, data, and decision making. Participants should be able to suggest mechanisms to change the program if their data show it to be ineffective. Empowerment evaluation is most often iterative and incremental. The teacher leaders would specify near term and local goals, determine when these goals were met, and then specify new goals. An analogy for this would be embedded classroom assessment planned by students.

What are Some Evaluation Methods to Determine the Effects of Teacher Learning Programs?

The first three sections provided definitions of evaluation related to evaluation philosophies, justifications for conducting evaluations, and potential evaluation questions. The following section provides specific suggestions for conducting an evaluation by describing various settings and data sources that are possible for information gathering. The examples are intended to be suggestive of various methods and are not an exhaustive set. These suggestions are based in different evaluation approaches and move out from first order effects to more general and wide spread effects (See Figure 1).

Evaluation of the Delivery of Professional Development

Evaluations of the delivery of teacher leader development can be both formative and summative. Formative evaluation is most useful in situations where similar sessions will be offered in the future. Evaluation can then provide valuable suggestions for improving these future sessions. If more sessions are not offered, evaluation can perform a summative function by documenting the quality of the sessions and their outcomes. Four common immediate techniques for either formative or summative evaluation of professional development are observations, participant opinion surveys, pre post testing of changes, and embedded participant participation.

Some powerful tools have been developed recently by Horizon Research, Inc. (HRI) (1999) for their evaluation of the National Science Foundation's Local Systemic Change (LSC) projects. The LSC program was designed to broaden the impact, accelerate the

Type of Effect	Evaluation Method
Delivery of Professional Development	Observations Participant Opinion Surveys Pre Post Testing Embedded Participant Participation
Effects on Teacher Leaders	Pre Post Testing of Changes Phenomenological Studies Discourse Content Analysis
Effects on Classrooms and Students	Ethnographies Assessment Within Classrooms Assessment of Student Outcomes
Effects Within Schools	Case Studies and Ethnographies Pre Post Testing
Effects on Districts or States	Student Outcomes Policy Analysis Network Analysis

Figure 1. Methods of Evaluation Useful in Determining Different Effects of Teacher Leadership Programs

pace, and increase the effectiveness of improvements in science and mathematics education at the K-12 level. The expectation is that teacher enhancement efforts, standards-based curriculum, parents, informal science and mathematics education institutions, local businesses and industries, nearby colleges and universities and local policies will all come together to achieve a common goal. The program is a mix of federal and local funds with the federal funds supporting teacher professional development, generally through the development of teacher leaders.

A unique aspect of the LSC program is its attention to evaluation. All of the LSC projects are required to participate in a nation-wide evaluation effort, termed the core evaluation, as well as individual evaluation efforts specifically related to local project goals. The core evaluation requirements are: to observe 5-8 professional development sessions per year, to administer 300 teacher questionnaires to teachers in the participating school districts, to administer principal questionnaires to all principals in participating districts, to conduct a minimum of 10 classroom observations, to conduct interviews with 10 randomly selected teachers, and to interview the project administrative team. To ensure uniform data collection, all of the requirements are supported by protocols, surveys or observation formats and evaluators are required to attend national sessions on the appropriate use of the instruments. All of the instruments are available through the HRI home page, www.horizon-research.com.

Observations

One common form of immediate evaluation of teacher leader professional development is observation of the sessions by experts. These observations should use protocols to guarantee comprehensiveness and consistency of the findings. The HRI Professional Development Observation Protocol is an excellent tool (Horizon Research, Inc. [HRI], 1999). It has several components including pre and post interviews with the professional development facilitator and a comprehensive observation protocol that is to be filled out after observing the session for a significant amount of time. The procedure is to interview the presenter, watch a significant portion of the session perhaps taking field notes, interview the presenter again, and then at a later time fill out the Professional Development Observation Protocol (HRI, 1999) using the interview results and the field notes.

The Observation Protocol begins by requesting information about the observer and the contextual background of the session such as the numbers and types of people attending and the focus of the session. Additionally, the observer is asked to categorize the activities the participants are engaged in as listening, reading, discussing, or other activities. After this contextual information the observer is asked to provide various types of ratings. The ratings move from more specific to more general with synthesis ratings at several stages. The synthesis ratings are not intended to be numerical averages of the individual ratings but instead are to represent a holistic impression of program quality.

The observer is first asked to rate the design, implementation, content (science or mathematics pedagogy and leadership), and culture of the session. These ratings include 5 point Likert scales of specific topics. The six items under leadership content are: 1) information on principles of effective staff development was sound and appropriately presented and explored, 2) information on strategies for mentoring and coaching peers was sound and appropriately presented and explored, 3) information on how to be a reform advocate at school or district level was sound and appropriately presented and explored, 4) facilitator(s) displayed an understanding of leadership concepts, 5) participants were intellectually engaged with important ideas relevant to the focus of the session, and 6) participants were given adequate and appropriate opportunity to consider how the content of the session applied to their particular leadership roles. Once the specific topics are rated, the observer is asked to provide a synthesis rating for that portion of the session. These ratings range from 1 to 5. A "1" for leadership content would be "leadership content not at all appropriate for preparing participants to be school or district leaders of mathematics or science education." A "5" for leadership content would be "leadership content highly appropriate for preparing participants to be school or district leaders of mathematics or science education." As additional examples, a "1" for design would be "design of the session not at all reflective of best practice for professional development." A "5" for science content would be "science content of session extremely reflective of current standards for science education." The synthesis ratings are followed by a space for open-ended responses from the observer to provide anecdotal, supporting evidence for the ratings.

After rating these categories, observers are asked to provide overall five point ratings of the likely impact of the session on the participants' capacity to provide high quality mathematics or science education (seven items) and leadership capacity (ten items). The leadership capacity items include the impact on the leaders' knowledge and understanding of mathematics and science, classroom practice, effective classrooms, prior knowledge of teachers, adult learners, the reform process strategies for reform, ability to plan professional development, confidence and networking. Following these sections, there is room for anecdotal comments.

At the end of the protocol the observer is asked to provide a single holistic rating for the overall session. A "1" is ineffective professional development. This is described as, "There is little or no evidence of participant thinking or engagement with important ideas of mathematics or science education." Session is unlikely to enhance the capacity of participants to provide high quality mathematics or science education or to be effective leaders of mathematics or science education in the district. A "5" is exemplary professional development which is highly likely to enhance participants capacity.

An example of a LSC grant project involves the Minneapolis Public Schools (Dr. Carol Johnson, Project Investigator). This project uses this form to evaluate their professional development efforts. One professional development session involved the designated lead teachers from various schools. These teachers spent a week defining important educational issues and studying research dealing with these topics. The facilitators were well prepared, supportive and knowledgeable. Teachers discussed their findings in small, similar interest groups and with the larger group. Overall, this session was given a "4", "accomplished, effective professional development". It was not given a "5" because the evaluator felt it did not adequately address how the teachers would use this information to lead others at their schools. The interviews with the facilitators revealed that they believed they were modeling the behavior the lead teachers would use in their schools. The evaluator felt, however, that more explication of the techniques being modeled and more practice with them would be necessary for it to be "highly likely" that the teachers would be able to use them effectively.

Participant Opinion Surveys

Another type of immediate evaluation is participant opinion surveys, which can use written or oral formats. These types of surveys are designed to gather information about the beliefs of the participants.

Participants are asked questions about the worth of the sessions to them, whether their expectations were met, and what might be done to improve the sessions. These surveys are most effective when they are short and collected at times when almost everyone's response can be obtained. Mailing in opinion surveys usually results in a low response rate. It is best to collect them as participants are leaving the professional development program. In sessions of several days, it is useful to have opinion surveys collected half way through so that the remainder of the session can be redesigned to better meet the needs of the participants. The surveys are also more effective when they contain a mix of rating items that target the attainment of specific goals along with a very small number of open-ended questions addressing the issues believed to be most controversial, most ambiguous or the most difficult to express as ratings.

The HRI survey is set up in an oral format. However, some of the items on the HRI Teacher Interview Form (HRI, 1999) could be formatted into questionnaire items. Interviews provide more in depth information but because of the large time constraints, data are gathered from only small numbers of participants. The HRI interview questions include: How do you feel about the professional development? What has been most helpful to you? What has been least helpful? How has the professional development affected you and your teaching? What else do you need to continue improving?

Another technique for obtaining opinions is the focus group (Krueger, 1994). In this technique, a trained focus group facilitator leads a carefully selected group of about 8-15 people in discussions of a small set of provocative questions. This interview technique is widely used in market research where groups of people are asked to try out a new product and then talk about it with each other. The advantage over individual interviews is that you can ask questions of several people at one time, which increases the sample size. Focus groups also provide the opportunity for interaction among respondents that is missing in both written surveys and individual interviews. This interaction helps the facilitator gauge the depth and consensus of feeling about the topics being discussed.

Pre Post Testing

A third type of immediate evaluation is pre post testing of changes in various targeted variables. Examples of pre and post testing variables include knowledge of leadership techniques, knowledge of other content, perceptions of self as a leader, feelings of empowerment or capacity to lead, or reported past and perceived future behavior. This type of evaluation is more summative in nature and outcome oriented than the participant opinion data described previously. It is also more complicated. In order to document that the participants have changed in a significant way, the instruments for measuring the change must be valid and reliable. There are some instruments that exist and can be used, such as, attitudes toward science, locus of control, personality indices, and understanding of science. Often, however, the goals of the program do not fit exactly with the existing instruments. In this case, new instruments may have to be developed with the concomitant pilot testing to establish feasibility, reliability and validity.

An example of this type of evaluation would be the Physics: A Modeling Approach Project (Dr. David Hestenes, Project Investigator, Arizona State University, Tempe, Arizona) which uses the Force Concept Inventory (Hestenes, Wells and Swackhamer, 1992). The instrument is used in a pre post fashion to determine if future teacher leaders changed their understanding about forces and motion during their professional development. Because the teacher leaders are to be teaching others about science concepts, it is important to know their levels of understanding. The measure provides both formative feedback in the sense of need for more professional development on specific areas of force and motion and summative feedback in the sense of how effective the session was in changing teacher leader understanding of these concepts.

Embedded Participant Participation

A final suggestion would be to use embedded participant participation. This method would involve the participants in the specification of goals for the session, mechanisms for achieving the goals and the designation of data that would demonstrate whether or not the goals were met. Because of the novice status of the participants in terms of evaluation, this could result in a less rigorous evaluation but the process would have the advantage of providing professional development simultaneously. In this case, an evaluation specialist can be used to help coach the participants. Care must be taken with the coach, however, so that the role is indeed coaching. Modeling this sort of coaching behavior is also a valuable source of professional development for the teacher leaders, since they may be required to act in this capacity in their own schools.

In the Minneapolis LSC project the lead liaison teachers are being coached in evaluation and at the same time in using evaluation as a mechanism for helping teachers in their designated schools to move forward in implementing the National Research Council's Science Education Standards (National Research Council, 1996). Meetings are structured where the liaison teachers discuss what they want to accomplish and how they and the evaluator would be able to help determine if their goals are being met. After these data are gathered, the group meets again to discuss the results and determine the next steps. In the schools, the liaison teachers form groups of teachers and together they discuss the best ways to move the school forward in meeting the standards and how they will know when they get there. These planning sessions help to clarify the goals and outcomes to the teachers and allow for their input.

Effects on Teacher Leaders

Pre Post Testing of Changes

The next step away from evaluating the professional development session itself is to examine the effect of the session on the teacher leaders. This provides evidence of the outcomes for the session.

The pre post testing described previously is a measure of the immediate effect of the session rather than a more long-term effect. The pre post testing could be also expanded to include a post-post test where the residual effects of the session would be ascertained. The same test can be used in all three situations. This type of testing can also show the moderating or enhancing effects of experience. Without the initial post test an evaluator would not know if pre to post-post changes were due to the session or to other factors. If there is no pre to post change but there is pre to post-post change, it may be difficult to attribute the change to the session(s). A more sophisticated quantitative design might include repeated measures (Howell, 1987) or time series analyses (Norusis, 1994).

Phenomenological Studies

Another way to study the effects on the teacher leaders would be to conduct phenomenological studies of the lived experiences of some of the teacher leaders. These types of studies are not generalizable across individuals but they do provide rich information about how the professional development impacted the life of the teacher leader. These types of studies take a great deal of time and effort but their advantage is that they do not force the experience into the narrow categories assessed in pre post and post-post testing. This type of evaluation is an excellent opportunity for the participants to be involved in the evaluation process. One approach may involve teachers keeping their own reflective journals and reviewing each other's experiences. This would not only help to consolidate the experiences through grounded theory but also spread information among the participants about what to do and what to avoid.

Discourse Content Analysis

Another way to study effects on teacher leaders is to analyze their conversations. Discourse content analysis (Kintsch, W., & van Dijk, T.A., 1978; Trabasso, T., van den Broek, P., & Suh, S., 1989) can be done during subsequent meetings and is used as a non-intrusive way to learn what issues are important to them and how they have responded. The major limitation is that the teachers may not talk about issues of importance to the evaluation. It is also difficult to use this type of analysis to make definitive statements about effects. Just because the teachers do not talk about something does not mean that they are not thinking about it. Also, something very important may be mentioned only once while irritating or minor things may be discussed at length. The analysis must proceed carefully and make suggestions not conclusions. This technique is particularly effective if the teacher leaders are part of an electronic communication system. The email discussions can be randomly sampled and a discourse content analysis can be conducted. Having a built in "transcription" of the conversation is invaluable for analyses. The Wisconsin Academy Staff Development Initiative (WADSI) (Dr. Julie Stafford, Project Investigator, Chippewa Falls, Wisconsin) has used the technique to monitor its teacher leaders and it has proven quite informative. Often inferences made from the discourse content analyses are verified with more quantitative survey techniques both on line and on paper.

Effects on Classrooms and Students

These types of evaluations would only be conducted if the program were claiming to have effects on classrooms. It is common in teacher leader programs to assume that the leaders will go back to their school or district and lead other teachers in reform efforts. This assumption would lead to the expectation of change in the classrooms of teachers led by the teacher leader, as well as change in the classrooms of the teacher leaders themselves. On the other hand, effects on classrooms and the students in them may be too far removed to be attributed to the professional development program. Students in particular are significantly affected by contexts other than school and therefore changes in their behavior are difficult to attribute to any program. Although many types of studies are possible, only three broad categories are discussed here: ethnographies, assessment within classrooms and assessment of student outcomes.

Ethnographies

Ethnographies of classrooms provide the richest data about how the professional development sessions have affected the classroom. Ethnographies are in depth descriptions about the participants, activities, context, and culture operating in particular settings. (Fetterman, 1989). Qualitative techniques are particularly useful for identifying unanticipated effects and in exposing the complex ways in which professional development can lead to change. This is an area where the teacher leaders themselves might be responsible for gathering the data. The most difficult part of qualitative studies is making sense out of the large amount of data gathered. In this scenario, the teacher leaders could be gathering data as they lived the experience and a skilled evaluator could help them make meaning perhaps through a series of focus groups.

Assessment Within Classroms

Assessment of teacher behaviors would require some sort of standard or comparison group against with to compare the behavior of the affected teachers. The science and mathematics standards could be used to formulate behavioral outcomes and then teacher growth on the stipulated behaviors could be measured. Comparison groups could be formed from teachers in schools that did not have teacher leaders. Then the behavior of teachers in one setting would be compared to the behavior of teachers in the other. In order for comparison groups to be effective, careful matching must occur. In teacher leader settings in particular, care must be taken to ensure that the schools and teachers are comparable to ensure that no selection bias exists. It is often the case that schools, or teachers, who are "good" to begin with, will be the ones choosing to participate in professional development. The pre post testing can be quite varied. It could include observations of pedagogy by external or internal "experts" or peers, content analysis of curricular materials and assessment devices, or student perceptions of teacher activity.

If observations are conducted to assess behavior, a careful protocol should be followed. Again, HRI has developed a Classroom Observation Protocol (HRI, 1999) that can be used to assess the effectiveness of science and mathematics classes. The Classroom Observation Protocol is very similar to the Professional Development Protocol (HRI, 1999) in format. It contains pre and post interviews with the teacher, contextual questions, individual topic ratings, synthesis ratings, an overall holistic rating and the opportunity to include anecdotal evidence in support of the ratings. Once again, the observer is expected to interview, observe, interview again, and then fill out the protocol.

The individual topics on the HRI instrument are grouped into design, implementation, mathematics or science content, and classroom culture. Each of these is given a five-point synthesis rating as well. Then the likely impact of instruction on student understanding of mathematics and science is rated, followed by a holistic rating of the overall lesson. Level 1 lessons are categorized as ineffective instruction, meaning there is little or no evidence of student thinking or engagement with important ideas of mathematics or science. Instruction is unlikely to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics or science. Level 5 lessons are categorized as exemplary instruction, meaning instruction is purposeful and all students are highly engaged most or all of the time in meaningful work; the lesson is well-designed and artfully implemented, with flexibility and responsiveness to students' needs and interests; instruction is highly likely to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" mathematics or science.

Classroom effects can also be assessed through determination of the classroom psychosocial environment. The most common way of assessing this is through a written form that students complete about how they feel about their classroom. Classroom learning environments have been shown to be related to positive student outcomes and to be sensitive indicators of differences in classrooms (Fraser, 1994). One recent form that is aligned with the standards is the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser, & White, 1994).

Assessment of Student Outcomes

Pre post and post-post testing of student outcomes can also be used to assess the effects of professional development. This type of assessment also requires a standard or comparison group to assess against. Student cognitive, attitudinal or behavioral outcomes can be assessed. There is a myriad of instruments available to assess student outcomes. Two reasonable and recent sources for achievement items are the National Assessment of Educational Progress (NAEP) and Third International Mathematics and Science Study (TIMSS) released items (www.nces.ed.gov). Using these items will allow a program to tie their students' achievement to national and international achievement levels. A critical issue in student achievement, attitude, and habits of mind and behavior assessment is deciding when is the most appropriate time to conduct the testing. In order to make this decision, one must decide when change should first begin to appear and how long it should be sustained. There is evidence that you need 2-5 years of implementation to get change in student achievement (Newman, 1996). There is also evidence that student and teacher outcomes are diluted through the "train teachers to train other teachers" approach (Lawrenz, 1986). The first cohort experiences the most significant effect and that decreases as you move out. This dilution, however, does not seem to be the case in the more recent teacher leader professional development models where the leader is directly involved in school or district based planning and development (WADSI Program, Dr. Julie Stafford, Project Investigator).

Effects Within Schools

Many recent teacher leader programs assume that the leaders will return to their districts or schools and become change agents that will stimulate and direct changes at the school level and thereby disperse and increase the effects of the original program. Therefore, examination of school effects is critical. Two qualitative and two quantitative techniques are suggested in the following two sections. A good reference on the effects of school reform, which contains quantitative and qualitative results, is Newman's (1996) study of restructured schools.

Case Studies and Ethnographies

The two most promising qualitative techniques are case studies of schools (Yin, 1989) and ethnography of the culture of the school

(Fetterman, 1989). The ethnography would be used to document the cultural changes that occur as a result of the actions of the teacher leader. This is similar to an anthropologist studying the effects on a native culture when a prominent tribal member returns from an encounter with another culture. The other methodology would be a case study of the school or schools and could include schools with and without teacher leaders or schools utilizing various types of professional development. The strength lies in the fact that several voices and perceptions can be included in the case study. Furthermore, the description is holistic and relates to the entire school. Case studies generally require a long-term relationship with the school and include observations, interviews, surveys, and collection of artifacts.

Pre Post Testing

There are two quantitative techniques that involve pre post testing. One technique is pre post and post-post testing of the culture of the school using surveys. Triangulation of the assessments is through the administration of surveys to three different information sources such as principals, teachers, and students (Louis, Marks & Kruse, 1996). The second technique is pre post testing of student outcomes. This would require that the program assumes that it will have some effect on student outcomes and has all the limitations associated with the effects on classrooms and students.

Effects Within Districts or States

These types of effects are a long way removed from the professional development of teacher leaders but they are often claimed as potential outcomes from these types of programs. There are three different methods that are most useful in determining these effects: student outcomes, policy analysis and network analysis.

Student Outcomes

Determination of student outcomes is a possibility for determining effects on districts or states, but as mentioned previously, it is difficult to track the attribution of training-a-teacher-to-be-a-teacher-leader to state or district wide changes in student achievement. What would probably be most important in this type of analysis is to clearly explain the lack of a direct relationship between student outcomes and teacher leader training.

Policy Analysis

Perhaps more relevant to documenting the effects of teacher leader training programs is policy analysis. This sort of analysis can be conducted at either state or district levels. It is reasonable to expect that a teacher leader program and the leaders it produces would be in positions to affect policies. A policy analysis could also include an analysis of changes in state or local professional education organizations.

Network Analysis

The third possibility is network analysis. This procedure is designed to show the development and strength of the various networks of power and communication existing within a system. In this case, the system would be a district or state. Network analysis would allow the determination of the degree of teacher leaders' involvement or the involvement of institutions containing teacher leaders in the power and communication structures. It would also identify existing power structures and the relationships of these power brokers to the professional development effort.

Summary

In summary, evaluation is a complex undertaking that cannot be simply defined. There are many different interpretations of evaluation and no single correct approach to evaluation problems. Different approaches are designed to address different needs and different questions. Evaluators of teacher leader development programs need to carefully articulate their program's goals and objectives with reasonable, valued and documentable outcomes. Next, specific evaluation questions based on the interests and values of the stakeholders need to be developed. These questions will depend on the type of effects the program is expected to produce. For example, a program may be expected to deliver quality professional development. Therefore, evaluation questions would focus on the professional development sessions themselves. On the other hand, the program may be designed to produce statewide changes in the educational system. Then the evaluation questions would focus on changes in educational policy or delivery. Once determined, the evaluation questions should be matched with appropriate information gathering techniques. Then the data is collected and analyzed. The final step is providing the information in a manner that meets the needs of the stakeholders, such as, state legislators, school superintendents, teachers, parents, and others. Providing useful data in appropriate formats is critical if the program is to survive and, if done well, can help the program to meet its goals.

References

Fetterman, D. (1989). *Ethnography step by step.* Newbury Park: Sage.

Fetterman, D. (1996). Empowerment evaluation: An introduction to theory and practice. In D. Fetterman, S. Kaftarian & A. Wandersman (Eds.), *Empowerment evaluation: Knowledge and tools for self-assessment and accountability.* Thousand Oaks: Sage.

Fetterman, D. (1997). Empowerment evaluation: A response to Patton and Scriven. *Evaluation Practice, 18 (3),* 253-266.

Fraser, B. (1994). Research on classroom and school climate. In D.L. Gabel (Ed.), *Handbook of research on science teaching and learning.* New York: Macmillan.

Hestenes, D., Wells, M. & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher, 30,* 141-158.

Horizon Research, Inc. (1999). *Local systemic change 1998-1999 core evaluation collection manual.* Chapel Hill, North Carolina: Author.

House, E. (1983). Assumptions underlying evaluation models. In G. F. Madaus, M. Scriven & D. L. Stufflebeam (Eds.), *Evaluation models.* Boston: Kluwer-Nijhoff.

Howell, David C. (1987). *Statistical methods for psychology, second edition.* Boston: Duxbury Press.

Joint Committee on Standards for Educational Evaluation. (1994). *The program evaluation standards, second edition.* Thousand Oaks: Sage.

Kintsch, W., & van Dijk, T.A. (1978) Toward a model of text comprehension and production. *Psychological Review, 85,* 363-394.

Krueger, R. (1994). *Focus groups: A practical guide for applied research, second edition.* Thousand Oaks: Sage.

Lawrenz, F. (1986). Teacher to student transfer in energy education. *School Science and Mathematics, 86 (1),* 1-9.

Louis, K., Marks H., & Kruse, S. (1996). Teachers' professional community in restructuring schools. *American Educational Research Journal, 33 (4),* 757-789.

National Research Council. (1996). *National science education sandards.* Washington, DC: National Academy Press.

National Science Foundation. (1997). *User friendly handbook for mixed method evaluations.* Washington DC: National Science Foundation, Directorate for Education and Human Resources, Division of Research, Evaluation and Dissemination.

Newman F. & Associates. (1996). *Authentic achievement: Restructuring schools for intellectual quality.* San Francisco: Jossey-Bass.

Norusis, Marija J. (1994). *Advanced statistics 6.1.* Chicago: SPSS Inc.

Patton, M. (1997a). *Utilization-focused evaluation, New century edition.* Thousand Oaks: Sage.

Patton, M. (1997b). Toward distinguishing empowerment evaluation and placing it in a larger context. *Evaluation Practice, 18 (2),* 147-163.

Phi Delta Kappa National Study Commission on Evaluation. (1971). *Educational evaluation and decision making.* Itasca IL: F.E. Peacock.

Scriven, M. (1991). *Evaluation thesaurus, Fourth edition.* Newbury Park: Sage.

Stake, R. (1968). The countenance of educational evaluation. *Teachers College Record, 68,* 523-540.

Stevens, F., Lawrenz, F., & Sharp, L. (1993). *User friendly handbook for project evaluation: Science, mathematics, engineering and technology education.* Washington DC: National Science Foundation, Directorate for Education and Human Resources, Division of Research, Evaluation and Dissemination, GAO OCG-93-6TR.

Taylor, C., Fraser, B. & White, L. (1994, April). *CLES: An instrument for monitoring the development of constructivist learning environments.* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans.

Trabasso, T., van den Broek, P., & Suh, S. (1989). Logical necessity and transitivity of causal relations in stories. *Discourse Processes, 12,* 1-25.

Worthen, B., Sanders, J. & Fitzpatrick J. (1997). *Program evaluation: Alternative approaches and practical guidelines, second edition.* White Plains, NY: Longman.

Yin, R. (1989). *Case study research design and methods.* Newbury Park: Sage.

15

Diversity, Technology, and Policy: Key Considerations in the Development of Teacher Leadership

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School change can be greatly impacted by teachers who take an active role in leadership. Teacher leaders should continue to expand their roles and influence in effecting the types of school reform that will lead to sustainable change in the quality of education. Since professional development is key to change, this chapter will address three areas that have not been adequately emphasized in the delivery of professional development programs: diversity, technology, and policy. Teacher leaders must be provided with opportunities to develop skills necessary to provide leadership relevant to these areas. This chapter provides some perspectives on the importance of these issues in reforming mathematics and science education and considers the roles of teacher leaders in influencing needed change.

The emergence of teacher leaders as integral members of schools' management teams has been a positive outgrowth of site management emphases during the last decade. Preceding chapters in this work have elaborated on the importance of teacher leaders and how professional development opportunities play a key role in fostering skills necessary for these leaders to become effective agents of change. As we look at the roles that teacher leaders will be asked to assume, it is particularly important to consider the types of leadership skills necessary for their work, as well as how those skills might best be enhanced and developed. The intent of this chapter is to explore these important considerations. Specifically, what kinds of skills will teacher leaders in mathematics and science education be required to demonstrate? And, how can we best achieve those ends through inservice and professional development opportunities?

In order to provide a context for an elaboration of these two questions, this chapter has been centered around three areas that are paramount to the successful reform of mathematics and science education. For teacher leaders in mathematics and science to be effective change agents, they must develop knowledge and skills in areas related to *diversity*, *technology*, and *policy making*.

Diversity

Recognizing Diversity Issues in Mathematics and Science Education

Our classrooms are diverse communities made up of growing numbers of individuals from increasingly varied backgrounds. Yet, unfortunately, positive experiences for many diverse learners in mathematics and science classrooms continue to be few and far between (Carey, Fennema, Carpenter, & Franke, 1995). As history has demonstrated, mathematics and science continue to serve as a filter, if not a gatekeeper, for full participation in our society (National Council of Teachers of Mathematics [NCTM], 1989; Tate, 1994). Sadly, this filtering process has often taken place along lines of gender, race, and socio-economic status (Carey et al., 1995; Ladson-Billings, 1995). Hence, if all learners in our schools are indeed entitled to equal educational and career opportunities, then mathematics and science teaching must undergo significant changes in order to reflect and honor the diverse cultures and contexts inherent in our schools and communities.

One of the daunting challenges in this area is to address the imbalances in the teaching force and our student population. The school age population in the United States continues to reflect an increasing diversity of racial, ethnic, and cultural groups. In many school districts, the majority of students are from minority groups (Banks, 1991). These changing demographics in school populations provide a stark contrast to a modest (at best) increase of teachers of color (Zeichner, 1996), estimated to be no more than 15% of the teaching force by the year 2000 (Banks, 1991). Hence, teachers will continue to be white, mostly monolingual, and will have backgrounds and experiences that vary considerably from many, if not most, of their students (Zeichner, 1996).

Moreover, it has also been shown that minority students and those at-risk are disproportionately taught by teachers who are less experienced and less qualified (Stover, 1999). Estimates from the

National Center for Education Statistics (cited in Stover, 1999) indicate that disadvantaged high school students are 50% to 100% more likely to be taught by a teacher without proper training in the subject. This situation is further compounded by the current crunch in demand for mathematics and science teachers. Estimates indicate that as many as 28% of grades 7-12 mathematics teachers, and 18% of science teachers, are teaching without academic major or minor degrees in those respective fields (Ingersoll, 1999).

Defining Roles for Teacher Leaders.

Given these troubling statistics, it would appear that a new generation of teacher leaders must embrace these issues of equity and diversity inherent in our mathematics and science classrooms, and take active leadership roles in making mathematics and science instruction relevant, engaging, and meaningful for all learners. Potential roles that teacher leaders should assume would first and foremost include the development of exemplary practices and "culturally relevant pedagogy" (Ladson-Billings, 1994) within their own classrooms. Malloy and Malloy (1998) stress the importance of having knowledge of classroom culture that promotes learning. This includes an understanding of the importance of multicultural education, the integration of multicultural materials and pedagogy into teaching, and an awareness of learning preferences so pedagogy can be adjusted to capitalize on those preferences. As other chapters in this volume have illustrated repeatedly, the modeling of best practice in mathematics and science instruction that teacher leaders can provide holds great promise for impacting change in school classrooms.

In addition to modeling teaching practices that honor and reflect the diversity of our classrooms, it would seem imperative that teacher leaders actively support and mentor new teachers so that they not only develop sound pedagogical practices, but also remain committed to teaching as a career calling. Given the already low percentages of teachers of color in the workforce, it is important for teacher leaders to take active roles in developing support structures and nurturing environments for teachers of color in the early stages of their careers. This is particularly important given that minority teachers can serve as the necessary change agents in schools and society through their clear and strong vision for social justice and their own perceptions of their roles in this change process (Su, 1998).

In short, teacher leaders can become actively involved in raising an awareness of the need for minority teachers by raising issues, developing and enacting policy decisions, and providing support to increase the numbers of minority teachers. Through teacher leaders, programs can be developed in schools to encourage and support minority students who have the potential to become teachers. Teacher leaders could extend programs such as Future Teachers of America, Teacher Cadets, Grow a Teacher, and Future Educators of America to give minority students opportunities to work with teachers in developing their interest in mathematics and science education. Mentoring programs that foster relationships between master teachers and minority teacher candidates provide a positive induction experience into the classroom (Futrell, 1999). Ultimately, minority teachers must be encouraged and mentored to become teacher leaders in the school and larger educational community.

Models For Professional Development

It is essential that our teachers have the knowledge, skills, and training necessary to reach diverse students (Futrell, 1999). Yet, even as fewer teachers from diverse backgrounds are being trained, teacher candidates report that their teacher education programs have inadequately prepared them to teach students from backgrounds dissimilar from their own (Ashton, 1996). As Cochran-Smith (1995) has suggested, there continues to be mounting evidence that "teachers are most able to understand, set appropriate expectations, and provide strategic support for students who are like themselves in culture, race, and ethnicity" (p. 542). Gomez (1996) has extended this notion to suggest that, not only are teachers apt to better support students who are similar in cultural background, they often view students who are unlike themselves "as children who are not only different, but deficient learners who are undesirable to teach" (p. 109).

In order to respond to these conceptions that teachers bring to their work, professional development must challenge teachers to confront these issues and to develop skills necessary in promoting equitable, multicultural mathematics and science education. Teacher leaders in particular must be central in this pursuit as they provide support for schools in implementing effective pedagogies to reach all students. Several models of this kind of professional development provide insight and examples for future work with teachers, and for the professional development of teacher leaders in particular.

Collaborative Redesign of Educational Systems in Texas (CREST) utilized a professional development school model under the guidance of mentor teachers and university faculty to continuously improve and assure equity and excellence among all learners (Patrick & Reinhartz, 1999). The program included tasks that examined issues of effective instructional strategies, principles of classroom management, and assessment as they apply to diverse settings. Participants also analyzed textbooks and materials for representation of people and issues from diverse populations, wrote and implemented lessons.

Mathematics Education, Equity, and Leadership (MEEL) is a professional development program committed to reforming mathematics education, promoting equity, and developing teacher leadership (Peterson & Barnes, 1996). The program has as its central mission the development of teacher leaders who are committed to equity in mathematics education. The program stresses fostering safe environments for learning so that teachers can be challenged to wrestle with important mathematics while also working toward relating mathematics to students' lives. The importance of creating such a mathematical community is instrumental in assisting teachers to consider constructivist teaching and change their practice (Pugalee & Malloy, 1999). In MEEL, conversations and discussions help teachers deal with deeply-held beliefs. The goal is to help teachers become aware of equitable mathematics reform as representative of personal as well as social change. Leadership is fostered through the development of confidence. Participants are given supported experiences in leading during the sessions. Through these opportunities, teachers are provided with active experiences to mold their confidence and to help each define what he or she needs to lead effectively. Through the interaction of these three objectives (reforming mathematics education, promoting equity, and developing teacher leadership) participants come to understand that learning is risky and leaders need to help create safe communities and contexts for learning and sharing.

In addition to programs focusing on the development of leadership, teacher leaders must become aware of effective programs that address the needs of minority students. Knowledge of such programs provides a framework for teacher leaders to identify the characteristics of successful programs as they plan and advocate for change in their own schools and communities. One example of such a program is the Science/Technology/Society (STS) approach that has a research and practice base spanning twenty years (Weld, 1999). The program emphasizes current issues in society and the lives of students as the foundation for study. Students are involved in planning the activities and become actively engaged in researching the issues and finding possible ways to resolve them. Students in this program demonstrate better attitudes toward science, improve their ability to apply science to daily problems, exhibit more equitable achievement outcomes in science across gender and ethnic lines, increase their decision making capacity, illustrate greater creativity, and perform on standardized tests as well as or better than students in traditional approaches. It is promising programs such as these that provide teacher leaders with information relative to educating diverse populations.

Summary: Equity, Diversity, And Teacher Leaders

The preceding paragraphs explored the roles and potential development of teacher leaders in fostering more equitable and relevant teaching in mathematics and science. Central to these roles and goals are the development of opportunities for teachers to address controversial issues on a personal and intellectual level so that they develop a better understanding of how these issues impact the culture of the school and community (Wiggins & Follo, 1999; Weissglass, 1994). Ladson-Billings (1994) asserts that successful teachers of diverse students need to develop knowledge of the community and the norms of the culture. Hollins (1995) notes that congruency between school culture and home culture facilitates communication, whereas differences interfere with communication and subsequently with learning. Particular to the study of mathematics, Tate (1994) has built upon this notion to suggest the importance of connecting the pedagogy of mathematics to the lives and daily experiences of diverse students. Toward that end, Ladson-Billings (1994) has identified three critical components of culturally relevant teaching: the teachers' conceptions of themselves and others; the manner in which classroom social interactions are structured; and teachers' conception of knowledge. Building on the successes of other programs that have been effective in addressing these components as articulated by Ladson-Billings should be the goal of those interested in helping teachers develop leadership ability in promoting equitable learning opportunities for children in mathematics and science classrooms.

Technology

Technology and Mathematics and Science Education

A second primary area around which professional development for teacher leaders should be focused is the area of educational technology. In the fields of mathematics and science, technology is viewed as an important tool, which supports the development of inquiry and assists in the solving of problems (NCTM, 1989; National Research Council, 1996). Classroom applications of technology (software programs, hand-held graphing calculators, Calculator Based Laboratories (CBL's), probe ware, and other tools) have significantly impacted not only *what* mathematics and science content is now emphasized in school curricula, but *how* that curricula is experienced by students.

In the past several years, technology has been poured into mathematics and science classrooms. The ratio of students per multimedia computer has decreased from 21 in 1996-97 to 14 in 1997-98. The number of classrooms connected to the internet reached 51 percent in 1998 (U. S. Department of Education, 1999). Hand-held graphing calculators have also been widely implemented and are now commonplace in high school classrooms. Likewise, CBL systems have similarly impacted mathematics and science instruction as this technology has allowed students to actively and individually experience various phenomena through authentic, inductive exploration. This integration of technology has demonstrated positive effects on student performance (Funkhouser, 1993; Wenglinsky, 1998), making it all the more important that teacher leaders develop the skills to guide and shape technology use in school mathematics and science classrooms.

Defining Roles for Teacher Leaders

As our society and schools become more technologically oriented, it is vital that teachers have the skills and knowledge to use these tools effectively and that teacher leaders assist in the development and implementation of technology plans for their schools and school systems. Teachers should have a voice in the technology plans that will ultimately impact curricular and instructional programs. School systems must have coordinated plans to provide the infrastructure, the hardware, the software, and the training resources necessary to effectively implement developed technology plans. Teacher leaders must be at the forefront of this endeavor to provide information and guidance, particularly related to the types of technology applications which best meet the needs of teachers and students (United States Congress Office of Technology Assessment, 1995).

Teacher leaders must also be able to provide expertise and guidance in the instructional *use* of technology. As suggested earlier, technology can support inquiry-based learning where students engage in active investigation of challenging content. Such explorations provide students with opportunities to understand difficult concepts earlier and more readily through interactive visualization, simulation, and hands-on modeling (United States Department of Education, 1999). All of this potential for student learning can be tapped if teacher leaders are prepared not only to model effective use of technology in their instruction, but also to work closely with colleagues in the development of school wide, cohesive use of technology.

Such leadership is vital given the current status of professional development in technology education. For example, a 1998 survey showed that only 20 percent of classroom teachers felt prepared to integrate educational technology into their instruction (United States Department of Education, 1999). Teachers report having low skills in designing lessons and classroom applications which utilize technology (Pugalee & Robinson, 1998; Willis & Mehlinger, 1996; United States Congress Office of Technology Assessment, 1995). Findings such as these confirm common sentiments shared informally and anecdotally in schools across our nation: while teachers recognize the wonderful promise of technology for the learning of their students, they feel overwhelmed by the task of developing the skills and aptitude to use it effectively in the classroom. The promise of effective inservice models, however, is evident. Instructional programs which provide teachers with training and opportunities to design and reflect on the instructional design process can have a significant positive impact on teachers' reported skills level (Pugalee & Robinson, 1998).

In order for teachers to use technology effectively, they must change the way they teach. Teachers who use technology change their teaching so that it is less teacher directed while providing students with a greater degree of autonomy (Nicaise & Barnes, 1996; Owston, 1997; Rogan, 1995; Topp, Grandgenett, & Mortenson, 1995). Many teachers also believe that the use of technology is controversial, stressing fears of students' over dependence on calculators (Milou, 1999). Simmt (1997) reported that teachers primarily used graphing calculators for verification of work and minimally in problem exploration. Perhaps the most challenging role facing teacher leaders, therefore, is to work toward the creation of effective professional development opportunities for teachers. Teacher leaders must find ways to provide ongoing support structures that not only provide for the development of technological skills and knowledge necessary for teachers to effectively plan instruction with technology integration, but also to assist teachers in changing their teaching philosophies, attitudes, and beliefs about the use of technology.

Professional Development for Technology Education

In order to effectively participate in such roles, teacher leaders must acquire technological expertise as well as the leadership skills necessary to promote and sustain instructional changes in their schools. Table 1 identifies the role of professional development in providing training about technology and with technology. Professional development must play a key part in providing teachers with basic information to be leaders in advocating effective technology plans and practices.

Technology itself has tremendous potential as a tool for professional development. Several professional development programs in mathematics and science demonstrate promise in providing the types of experiences teacher leaders need in order to impact classroom instruction and, ultimately, the learning of students. Two technology oriented systems, MathLine and Education Future Center (EFC), are highlighted in the following paragraphs.

MathLine provides participants with multimedia experiences designed to assist them in implementing reform based teaching practices into their classroom. The program is developed by the Public Broadcasting Corporation (http://www.pbs.org/mathline/). There are programs designed for elementary, middle, and secondary teachers. Professional quality video segments of classroom teachers provide participants with cases of actual classroom experiences. These cases present teachers with models of effective pedagogy and encourage reflection related to significant reform ideas. On-line discussion forums provide participants with opportunities to extend their professional community outside their physical school setting. The discussions offer a forum for teachers to discuss implementation of reform based teaching practices. Lesson resources provide substantive detail including information on important concepts and the types of inquiry based questions that will promote student learning.

Table 1. The Role of Technology in Professional Development Projects

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Training About Technology

- Acquainting teachers with the use of a specific technology
- Familiarizing teachers with a variety of technology tools and applications
- Training teachers to use technology to facilitate new instructional approaches
- Teaching teachers to integrate technology into a specific subject
- Helping teachers learn to incorporate technology across the curriculum

Training With Technology

- Delivering telecourses or teleconferences by satellite
- Videotaping training sessions
- Videotaping and critiquing of teacher performance
- Modeling good instruction on video
- Using Computer-assisted training modules for independent study
- Using laboratory tools for research assignments or internships
- Using telecommunications networks for research, interaction, and collegial work
- Providing computer databases on instructional issues
- Providing computer or video guides to accompany training materials

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Adapted from United States Congress, Office of Technology Assessment, 1995, p. 235.

The Education Future Center is a consortium of partners in education, government, business, and foundations spearheaded by the North Carolina School of Science and Math. The consortium has seven Cyber Campuses spread throughout the state. These Cyber Campuses are technology rich environments which provide opportunities for interaction and collaboration on regional, national and international levels. Discussion groups of staff and partners provide a means of sharing information and discussing and offering solutions to problems. Teacher workshops are currently being offered under the Education Future NOW program. Three benchmarks guide the current program: core technology skills, integrating technology into the classroom, and job-embedded learning (http://www.efc.ncssm.edu/).

The core technology skills benchmark includes basic applications of technology as well as development of knowledge in the ethical use of technology and the development of skills necessary to access, analyze, and communicate information for problem solving. The second benchmark is concerned with themes and newer concepts related to specific content and grade levels, the ability to use technology to access data, visualize concepts, and engage students in inquiry. These workshops are designed to promote peer collaboration and reflective practice. The third benchmark encourages the development of independent professional development plans, classroom research, pairing with peers for lesson development and assessment, formation of study groups, and capacity building through professional writing, conference presentations, and development of multimedia projects.

There also appears to be some promise in providing professional development opportunities for teacher leaders through participation with university teacher preparation programs. In a recent study, Frykholm and Meyer (in press) explored the impact of an innovative college course that had as its students a mixture of preservice teachers, graduate students (who served as student teacher supervisors), and practicing classroom teachers (who also served as cooperating teachers for the internship experience of the preparation program). The course focused on innovative and recent technological applications for the classroom, while at the same time building on the collaborative relationships that were emerging among the constituents in the course. Powerful collaborations emerged which were found to positively impact not only the knowledge and skills of the teachers, but also their work together in the school setting.

Summary: Technology and Teacher Leadership

This discussion on technology has underscored the importance which technology plays in the improvement of mathematics and science learning. Also evident was the significant role which teacher leaders must play in effecting the types of changes that will result in the effective use of educational technologies. The discussion substantiates the importance of teacher leaders in fulfilling the strategic recommendations of the President's Committee of Advisors on Science and Technology (1997): focus on learning with technology, not about technology; emphasize content and pedagogy, and not just hardware; give special attention to professional development; engage in realistic budgeting; ensure equitable, universal access; and initiate a major program of experimental research. Technology is a learning tool that will continue to dramatically alter the study of mathematics and science. In order to capitalize on the potential of this tool, teachers must become actively involved in providing the types of technology leadership which will allow our schools to adequately prepare students today and in the future.

Policy

Policy and Teacher Leadership

Over the last decade, there have been important increases in the opportunities for teachers to become involved in leadership. This new sense of ownership has advanced the professionalization of teaching and improved both teacher and student learning. These multiple opportunities have thrust teachers into experiences as mentors of new teachers, coaches to other leaders, peer evaluators, members of team-teaching groups, specialists to assist colleagues with competency issues, curricula writers, designers of professional development, writers and speakers about teaching and learning, researchers, and models of more accomplished teaching practices (Urbanski & Nickolau, 1997).

These new roles require new ways of thinking about teachers and teacher leaders in particular. In order for these new ways of thinking to change the culture of schools and school leadership, policy must also come to reflect the values of teacher leadership. Urbanski and Nickolau (1997) have drawn attention to implications of these developments by identifying some areas to consider if teacher leadership is to become established as an integral component of effective schools:

- teachers must be provided with opportunities to engage in policy making.
- new roles for teacher leadership must be extended and supported.
- support must include more time and increased access to new knowledge and skills (pp. 249-250).

Roles and Opportunities for Teacher Leaders in Policy Making

There is a growing body of research that suggests that teacher leaders must be more closely linked to the processes whereby policy decisions are made. Sherrill (1999) refers to this fundamental challenge in fostering teacher leadership by noting research that demonstrates that teachers have been unresponsive to top-down initiatives calling for the improvement of teaching. Research indicates that teachers are more likely to impact their practice as a result of collaborative interactions with colleagues (Mitchell, 1997; Wasley, 1991; Rosenholz, 1989). Such collaborative environments are crucial in the development of positive school climate (Whitaker, 1995; Firestone, 1993) and important in allowing the exchange and debate of ideas, which leads to professional autonomy (Castle & Aichele, 1994). Hence, facilitating processes whereby teachers assume leadership roles has become increasingly important.

One specific role of teacher leaders is to work toward creating the mechanisms whereby teachers' collective voices may be heard. In order to facilitate this process, teacher leaders should help colleagues form groups and unify their voices such that they may participate in the decisions that shape the work and mission of their schools. Presently, teachers largely work in isolation. To overcome this current level of isolation, schools must involve teachers at a higher level in collaborative experiences, professional development, and leadership. The involvement of groups of teachers who have the support of the school and district administration, students, parents, and the broader school community was identified by Clarke (1994) as one of the ten important principles of professional development. Involvement of such a grand scale will require policy decisions that provide mechanisms to support teachers with materials, resources and time.

As suggested earlier, teacher leadership roles must also be developed to allow for exemplary practicing teachers to assist other teachers, particularly inexperienced ones (Hyde, Ormiston, & Hyde, 1994). This is especially important in identifying subject area specialists, particularly in mathematics and science, who can provide ongoing support and information to teachers, and help them adapt to the major changes in curriculum, scheduling, and assessment demanded by reform methodologies (Windschitl, 1999). In this vital time of reform in mathematics and science education, the need for teacher leaders in the effective identification, implementation, and evaluation of such practices is essential. In addition, the roles of teacher leaders should be extended to allow for the impact of these leaders in influencing policies and practices within their districts as well as the state and nation.

Models and Directions for Professional Development

Teachers' responsibilities make it difficult for them to access the kinds of information and acquire the types of skills necessary to develop leadership. Opportunities must be provided, therefore, for teachers to have access to such resources. Some successful approaches reported by Firestone (1993) include large-scale staff development modeling active learning such as Gheens Academy in Louisville and Schenley High in Pittsburgh, the use of professional development schools combining inservice for current teachers with preservice preparation, and the use of teacher networks such as the Ford Foundation's Urban Mathematics Collaboratives, Coalition for Essential Schools, and California's Math A Network.

The professional growth of teachers is greatly limited by a lack of time for professional reading and reflection, a lack of joint planning time with other teachers, and a lack of opportunities to work together in classrooms (Clarke, 1994). Teacher leaders' lack of time with students and colleagues was identified as a major barrier to professional growth (LeBlanc & Shelton, 1997). These barriers greatly constrict the abilities of teacher leaders to positively effect change in instruction. Policy makers must therefore begin to change organizational structures of schooling that contribute to professional isolation if teachers and teacher leaders are to have time and accessibility to peruse and reflect on the knowledge necessary to gain new skills.

Teacher leaders must have opportunities to develop new skills that are necessary to extend their roles in the classroom to include work with adult peers (Sherrill, 1999). These skills include the ability to develop relationships and nurture the growth and development of other teachers. Specific to this task would be development of skills that would lead to observations of classroom instruction, and mentoring of teachers as well as consulting on issues related to classroom management, lesson development, and effective instructional practices. Table 2 identifies some of these core expectations for teacher leaders (Sherrill, 1999).

Table 2. Core Expectations for Teacher Leaders

- Demonstrate exemplary classroom instruction and sound knowledge of effective teaching and learning strategies.
- Understand theories of adult development.
- Demonstrate knowledge of clinical supervision models and processes that support effective descriptions of classroom practices.
- Cultivate desired dispositions in teachers.
- Guide colleagues by a reflective and inquiry-oriented posture.
- Possess research-based knowledge about teaching and learning.

Based on Sherrill, 1999, p. 60.

Summary of Teacher Leadership and Policy

Designers of professional development for teacher leaders have not paid adequate attention to the development of skills that are necessary for influencing and making policy decisions. The National Board for Professional Teaching Standards recognizes the essential nature of such skills in one of the five propositions in their standards for national certification. Proposition five states that "Teachers are members of learning communities." Elaboration of this proposition characterizes the effective teacher as one who works collaboratively with other professionals on instructional policy, curriculum development, and staff development. Further, they can evaluate school programs and the allocation of school resources (Darling-Hammond, Wise, & Kline, 1995). Such expectations do not support passive roles for teachers who only exert influence within the realm of their individual classrooms. Teachers must be leaders who work to influence the policy directions which impact their schools and their profession. The scarcity of professional development programs that target the development of such skills is alarming. If teacher leaders are to *lead*, professional development must begin to address how to best prepare the participants to assume roles within their schools, districts, and larger educational communities that will guide the decision making machinery which ultimately impacts individual student learning.

Conclusions

As professional development opportunities designed for teacher leaders strengthen components in the above considerations, our teachers will be better prepared to deal with these issues within the complex educational community. In this paper, we have attempted to highlight some of the roles that teacher leaders might assume, as well as mechanisms to provide development opportunities for teachers to be willing and able to embrace these new roles. In so doing, we also pointed toward three key issues that will fundamentally shape the direction and success of reforms in mathematics and science education. Specifically, issues of diversity will become more vital as our schools become more diverse. We must respond to these changes so that mathematics and science no longer act as the gatekeepers for large portions of our student population. Technology will continue to be a major factor in the future education of young mathematicians and scientists. Our teachers must lead this call not only by using technology in the classroom to enhance the learning experiences of students, but also to prepare them for successful entry into an ever-more technologically oriented society. Finally, the political landscape will require ever-increasing expertise on research and related issues in order for our teacher leaders to provide the necessary leadership to guide changes in curriculum and instruction. The consideration of these factors is key to strengthening the capabilities of our teachers to develop as leaders of the profession.

References

Ashton, P. T. (1996). Improving the preparation of teachers. *Educational Researcher, 25*(9), 21-22, 35.

Banks, J. (1991). Teaching multicultural literacy to teachers. *Teaching Education*, *4*(1), 135-144.

Carey, D.A., Fennema, E., Carpenter, T., Franke, M. L. (1995). Equity and mathematics education. In W. Secada, E. Fennema, & L. Adajian (Eds.), *New directions for equity in mathematics education.* New York: Cambridge University Press.

Castle, K. & Aichele, D. B. (1994). Professional development and teacher autonomy. In D. B. Aichele & A. F. Coxford (Eds.), *Professional development for teachers of mathematics,* pp. 1-8. Reston, VA: National Council of Teachers of Mathematics.

Clarke, D. (1994). Ten Key Principles from Research for the Professional Development of Mathematics Teachers. In D. B. Aichele & A. F. Coxford (Eds.), *Professional development for teachers of mathematics,* pp. 37-48. Reston, VA: National Council of Teachers of Mathematics.

Cochran-Smith, M. (1995). Uncertain allies: Understanding the boundaries of race and teaching. *Harvard Educational Review, 65*(4), 541-570.

Darling-Hammond, L., Wise, A. E., & Klein, S. P. (1995). *A license to teach: Building a profession for 21st-century schools.* Boulder, CO: Westview Press, Inc.

Firestone, W. A. (1993). Why "professionalizing" teaching is not enough. *Educational Leadership, 50*(6), 6-11.

Frykholm, J.A., & Meyer, M.R. (in press). Preparing teachers in an age of reform. *Educational Leadership.*

Funkhouser, C. (1993). The influence of problem-solving software on student attitudes about mathematics. *Journal of Research on Computing in Education, 25*(3), 339-346.

Futrell, M. H. (1999). Recruiting minority teachers. *Educational Leadership, 56*(8), 30-33.

Hollins, E. R. (1995). Revealing the deep meaning of culture in school learning: Framing a new paradigm for teacher preparation. *Action in Teacher Education, 17*(1), 70-79.

Hyde, A., Ormiston M., & Hyde, P. (1994). Building professional development into the culture of schools. In D. B. Aichele & A. F. Coxford (Eds.), *Professional development for teachers of mathematics,* pp. 49-54. Reston, VA: National Council of Teachers of Mathematics.

Ingersoll, R. M. (1999). The problem of underqualified teachers in American secondary schools. *Educational Researcher, 28*(2), 26-37.

Ladson-Billing, G. (1994). *The dreamkeepers: Successful teachers of African American children.* San Francisco: Jossey-Bass.

Ladson-Billing, G. (1995). Making mathematics meaningful in multicultural contexts. In W. Secada, E. Fennema, & L. Adajian (Eds.), *New directions for equity in mathematics education.* New York: Cambridge University Press.

LeBlanc, P. R. & Shelton, M. M. (1997). Teacher leadership: The need of teachers. *Action in Teacher Education, 19*(3), 32-48.

Malloy, C., & Malloy, W. (1998). Issues of culture in mathematics teaching and learning. *Urban Review, 30*(3), 245-257.

Milou, E. (1999). The graphing calculator: A survey of classroom usage. *School science and mathematics, 99*(3), 133-139.

Mitchell, A.. (1997). Teacher identity: A key to increased collaboration. *Action in Teacher Education, 19*(3), 1-14.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: The Council.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Nicaise M., & Barnes, D. (1996). The union of technology, constructivism and teacher education. *Journal of teacher education, 47*(3), 205-212.

Owston, R. (1997). The World Wide Web: A technology to enhance teaching and learning. *Educational Researcher, 26*(2), 27-33.

Patrick, D., & Reinhartz, J. (1999). The role of collaboration in teacher preparation to meet the needs of diversity. *Education, 119*(3), 388-400.

Peterson, P., & Barnes, C. (1996). The challenge of mathematics, equity, and leadership. *Phi Delta Kappan, 77*(7), 485-492.

President's Committee of Advisors on Science and Technology. (1997). *Report to the president on the use of technology to strengthen K-12 education in the United States.* Washington, DC.

Pugalee, D. K., & Malloy C. E. (1999). Teachers' actions in community problem solving. *Mathematics teaching in the middle school, 4*(5), 296-300.

Pugalee, D. K., & Robinson, R. (1998). A study of the impact of teacher training in using Internet resources for mathematics and science instruction. *Journal of Research on Computing in Education, 31*(1), 78-88.

Rogan, J. (1995). *The use of the Internet by math and science teachers: A report on five rural telecommunications projects*. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco.

Rosenholtz, S. (1989). *Teachers' workplace: The social organization of schools*. New York: Teachers College Press.

Sherrill, J. A. (1999). Preparing teachers for leadership roles in the 21st century. *Theory into Practice, 38*(1), 56-61.

Simmt, E. (1997). Graphing calculators in high school mathematics. *Journal of Computers in Mathematics and Science Teaching, 16*(3), 269-289.

Stover, D. (April 1999). The least qualified teach the most needy: Working to fix it. *Education Digest, 64*(8), 40-43.

Su, Z. (1998). Becoming teachers: Minority candidates' perceptions of teaching as a profession and as a career. In D. J. McIntyre & D. M. Byrd (Eds), *Strategies for career-long teacher education,* pp. 179-198. Thousand Oaks, CA: Corwin Press.

Tate, W.F. (1994). Race, retrenchment, and the reform of school mathematics. *Phi Delta Kappan, 75(6),* 477 - 484.

Topp, N., Grandgenett, N., & Mortenson, B. (1995). Research project: An appraisal of the impact of Nebraska's statewide internet implementation. In D. A Willis, B. Robin, & J. Willis (Eds.), *Technology and Teacher Educational Annual, Proceedings of the International Conference of the Society for Information Technology and Teacher* Education, pp. 743-746. Charlottesville, VA: Association for the Advancement of Computing in Education.

United States Congress, Office of Technology Assessment. (1995). *Teachers and Technology: Making the connection.* Washington, DC: U.S. Government Printing Office.

United States Department of Education. (1999). The educational excellence for all children act of 1999. *Education Week, 28*(39), 28-54.

Urbanski, A. & Nickolau, M. B. (1997). Reflections on teachers as leaders. *Educational Policy (11)*2, 243-254.

Wasley, P.A. (1991*). Teachers who lead: The rhetoric of reform and the realities of practice.* New York: Teachers College Press.

Weissglass, J. (1994). Changing mathematics teaching means changing ourselves: implications of professional development. In D. B. Aichele

& A. F. Coxford (Eds.), *Professional development for teachers of mathematics*, pp. 67-78. Reston, VA: National Council of Teachers of Mathematics.

Weld, J. (1999). Achieving equitable science education: It isn't rocket science. *Phi Delta Kappan, 80*(10), 756-758.

Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics.* Princeton, NJ: Educational Testing Service.

Whitaker, T. (1995). Accomplishing change in schools: The importance of informal teacher leaders. *Clearing House, 68*(6), 356-357.

Willis, J. & Mehlinger, H. (1996). Information technology and teacher education. In J. Sikula (Ed.), *Handbook of research on teacher education*, pp. 978-1029. New York: Simon & Schuster Macmillan.

Wiggins, R. A. & Follo, E. J. (1999). Development of knowledge, attitudes, and commitment to teach diverse student populations. *Journal of Teacher Education, 50*(2), 94-105.

Windschitl, M. (June 1999). The challenges of sustaining a constructivist classroom culture. *Phi Delta Kappan, 80*(10), 751-755.

Zeichner, K. (1996). Educating teachers for cultural diversity. In K. Zeichner, S. Melnick, & M. Gomez (Eds.), *Currents of reform in preservice teacher education*. New York: Teachers College Press.

“This timely book approaches the subject of leadership among science and mathematics teachers during times of educational reform from the perspective of local decision making, personal action, and respect of peers. The view of leadership presented in this book elevates the profession rather than the status of individuals, and the view is supported by positive outcomes in the everyday communities of schools. During the years of ongoing reform in education, we have focused on goals, standards, teacher preparation, materials, and curriculum frameworks. Ultimate success in reforming practice, however, will come when some key people at the local level lead the way in making decisions, taking action, and maintaining resolve to improve practices grounded in tradition.”

Foreword

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